Computed Tomography-Guided Percutaneous Radiofrequency Ablation of Metastatic Lung Nodules – Initial Experience and Outcome in Nonsurgical Candidates

SIU-CHEUNG CHAN¹,⁵ HUI-PING LIU² WINNIE CHIU-WING CHU³ Tzu-PING CHEN⁴,⁵

Department of Diagnostic Radiology¹, Division of Thoracic Surgery⁴, Chang Gung Memorial Hospital at Keelung
Division of Thoracic Surgery², BenQ Medical Center, Nanjing, China
Department of Diagnostic Radiology³, the Chinese University of Hong Kong, Hong Kong
College of Medicine⁵, Chang Gung University

To report the experience and outcomes of percutaneous computed tomography-guided radiofrequency ablation for nonsurgical candidates with repeat lung metastasis.

This study was carried out on three female patients (age range, 17-36 years; mean age, 24 years) with repeat lung metastasis. The three metastatic nodules were underwent percutaneous computed tomography (CT)-guided radiofrequency ablation (RFA) successfully after administration of local anesthesia. Subsequent CT scans were scheduled 3-month intervals post-procedure to assess the tumor control.

No lethal complications, major bleeding or bronchial damage was observed in all of our patients. Satisfactory tumors control was demonstrated by CT scan at subsequent three-month follow-ups.

CT-guided percutaneous RFA for lung metastasis is one of the treatment options for nonsurgical candidates, with minimal invasion and have achieved satisfactory tumor control.

Image-guided percutaneous radiofrequency ablation (RFA) is a widely recognized and applied therapy that has proved efficacious for lung, kidney, liver and bone neoplasm. It is gaining acceptance as an alternative therapy for patients with small-volume disease who are not surgical candidates. More than 2000 treatments have been performed worldwide, and the safety profile is well understood [1]. Short-term efficacy studies have shown good response rates, particularly for smaller tumors [2, 3]. Complete necrosis rates of 100% have been reported in tumors < 3 cm in diameter [3]. We demonstrated survival in three complex patients with lungs metastases. These patients, who were not candidates for surgery, were effectively treated by CT-guided percutaneous RFA.

PATIENTS AND METHODS

Patients

The institutional review board of our hospital approved a human use protocol. Informed consent forms were signed by all of the patients prior to the procedures. A total of 3 pulmonary nodules in 3 patients (all were female patients; mean age, 24 years; age range, 17-36 years) were treated with CT-guided percutaneous RFA between July 2008 and November 2008, and all patients had follow-up CT scans every 3 months for 12 months until October 2009.

Two of the patients had alveolar soft part sarcoma, in the thigh and calf, respectively, and the third had the rectal cancer. All had previously undergone surgical excision of the primary tumors.

The first patient, a 19-year-old female, was diagnosed with pulmonary metastases and received
Percutaneous CT-guided RFA of thoracic masses

video-assisted thoracoscopic (VAT) wedge resection of the metastatic lung nodules in both lungs on the fourth postoperative year. Repeat lung metastasis was found 7 months after the VAT wedge resection. A soft tissue nodule measuring about 1.5 x 1.2 x 1.3 cm was found in the right pleura.

The second patient, a 17-year-old female with pulmonary metastases twelve months after surgical resection of the primary tumor, underwent VAT wedge resection of the metastatic lung nodule in both lungs. A subpleural nodule at the medial aspect of the left upper lobe of lung 1 cm from the left lateral aspect of the pericardium was found during the regular CT follow-up nine months after VAT wedge resection. The nodule measured about 1.5 x 1.5 x 1.5 cm.

The third patient, a 36-year-old female, had rectal cancer, with pulmonary metastases found on the fourth year after surgical resection of the primary tumor. She also underwent VAT wedge resection of the metastatic lung nodule in both lungs. A soft tissue nodule measuring about 1 x 1 x 1.2 cm in the left upper lobe of the lung was found on the fourteenth month after the VAT wedge resection. The nodule measured about 1.5 x 1.5 x 1.5 cm.

Due to postoperative scarring with fibrosis in both lungs, none of these three patients was considered a suitable candidate for surgical intervention and RFA was therefore considered as an optional treatment for the repeated lung metastases.

Equipment and Procedure

The RF system consisted of a generator, an active electrode and grounding pads. The RF generators had a frequency of 480 kHz and a power output of 100-200 W. Digital displays on the front of the device indicated the power output, impedance value and procedure time (RF3000; Boston Scientific Corporation, Boston, Mass). The RF electrodes used (LeVeen; Boston Scientific) were 14-gauge multitine expandable electrodes 15 cm in length, with the selection of a 2.0-, 3.0-, 3.5- or 4.0-cm array diameter when fully expanded. The type of active electrode used was selected based on the size and location of the tumor; an electrode at least 10 mm larger than the diameter of the tumor was used to ensure an adequate ablation margin of 5-10 mm. The width of deployment was subsequently measured by CT; the treatment algorithm chosen was based on this measurement. A 3.0-cm electrode was used for all patients, and insertion was carried out under CT guidance. Although the lung nodule of the second patient was quiet close to the mediastinum, the tip of the electrode was approached into the nodule successfully from the route of lateral oblique under CT-guidance. The tip was positioned in or near the center of the tumor so deployed arrays could reach the farthest margin of the tumor, and to monitor the effect of the treatment. A 2-phase impedance-based algorithm was used and the treatment was delivered until a major increase in impedance occurred, in less than 15 minutes. A second RF delivery was then performed in the same location until a new major rise in impedance occurred, with 70% of the maximum power delivered to obtain this rise. The location of ablation was monitored by CT every 3 minutes during ablation to follow the procedure and to identify potential complications and provide immediate treatment when required. For sedation, the patients received 50 mg pethidine (Demoral; Roche, Basel, Switzerland) with or without 5 mg midazolam (Dormicum; Roche, Basel, Switzerland).

Postprocedural evaluation

A complete chest CT scan was performed immediately after electrode removal at the end of the treatment. A repeat CT scan was performed 24 hours after the procedure to evaluate the type and frequency of any complications. Follow-up CT scans of patients were carried out 3-month intervals. Changes in tumor mass after RFA were measured according to the Response Evaluation Criteria in Solid Tumors (RECIST) protocol [4, 5], which is based on objective measurements of lesion size before and after treatment. Complete response (CR) means lesion disappearance; partial response (PR), at least a 30% decrease in the sum of the longest diameter of target lesions; progressive response (PD), at least a 20% increase in the sum of the longest diameter of target lesions; and stable disease (SD), neither sufficient shrinkage to qualify for partial response nor sufficient increase to qualify for progressive disease.

RESULTS

All procedures were well tolerated, with no lethal complications and only minimal pneumothorax not requiring intervention occurring in the 19-year-old patient. No lethal hemorrhage, pleural effusion or pneumothorax with additional treatment was required in any of the patients. Follow-up with CT scans was performed every three months after the procedures to evaluate the treated metastatic nodules. Complete response of the right pleural...
Figure 1. a. A CT scan of the 19-year-old patient showed a right pleural tumor implantation. The lesion measured 1.5 x 1.2 x 1.3 cm. b. The electrode tip and its deployed arrays within the nodule from the posterior approach. c. A follow-up CT scan at 3 months showed minimal enlargement of the right pleural nodule. d. After 12 months, a CT scan showed complete regression of the right pleural nodule.

Figure 2. a. A CT scan of the 17-year-old patient showed a tiny subpleural nodule at the medial aspect of the left upper lobe of the lung less than 1 cm from the pericardium. The nodule measured approximately 1.5 x 1.5 x 1.5 cm. b. The electrode tip and its deployed arrays within the nodule from the lateral oblique approach. c. A follow-up CT scan at 3 months showed minimal enlargement of the retrocardia nodule with a wedge-shape appearance. d. After 12 months, a CT scan showed significant regression of the left upper lobe nodule.
nodule in the 19-year-old patient and the left upper lung nodule in the 36-year-old patient was evident at the 6-month follow-up, while linear scarring and cavitations were found in the latter patient. Significant shrinkage of the subpleural nodule in the left upper lobe in the 17-year-old patient was observed by CT 6 months after the procedure. No recurrence of the treated nodules was found at the 12-month follow-up (Fig. 1-3).

**DISCUSSION**

Surgical intervention is the treatment of choice for resectable lung cancer and lung metastasis, and offers the best chance of cure [6, 7]. When surgery is not an option, CT-guided percutaneous RFA may be a safe and effective alternative for local control of non-small cell lung cancer and pulmonary metastasis. Treatment can be performed with conscious sedation with minimal invasion and low complication rates. Complications of the procedure will also be apparent with follow-up imaging. The reported incidence of pneumothorax is approximately 40%, with 10-15% requiring intervention depending on the patient population [8]. Emphysema, absence of previous surgery, middle and lower lobe location, treatment of multiple tumors, and length of needle trajectory increased the chance of a pneumothorax [9]. Hemorrhage is usually obvious and self-limiting. Infective complications and recurrence can be more subtle [10].

In Akeboshi [2], tumor size was found to be a significant factor in therapeutic response to lung RFA. Small tumors (<3 cm) responded well (71%) to initial RFA. Complete necrosis was achieved equally in primary and secondary lung cancers [2]. The results suggest that lung RFA may provide important benefits to patients with unresectable pulmonary metastases, as no effective treatment has been established for many of these patients.

All of our patients underwent resection of the pulmonary metastasis with recurrence. Pleural adhesion induced by the first operation made the surgery for the recurrent metastasis extremely difficult. Almost all of the nodules were less than 2 cm at the longest diameter. CT-guided RFA should be the treatment option for these patients and we have achieved satisfactory tumor control in all of them.

The aim of therapy is to ablate the tumor in its entirety. Extending the margin of thermal ablation into apparently normal tissue adjacent to the tumor is necessary as tumor cells often infiltrate into this region. As ablation should encompass the whole tumor with a margin of apparently normal lung

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**Figure 3.** a. A CT scan of the 36-year-old patient showed a tiny nodule in the left upper lobe of lung. The nodule measured approximately 1 x 1 x 1.2 cm. b. The electrode tip and its deployed arrays within the nodule from the posterior approach. c. A follow-up CT scan at 3 months showed that the ablation zone had reduced in size with cavitation. d. The ablation zone became a small cavitation and linear scar formation in CT scan 12 months after radiofrequency ablation.
parenchyma, the overall lesion size should be greater than the baseline tumor for the first few months post-ablation. Therefore the ablation zone should be larger than the original tumor. This should not be confused with tumor progression [11]. The overall size of the ablation zone increases to a maximum at 1 week and then decreases again [11, 12].

In the post-ablation follow-up CT scans, between 1 week and 1 month the zones become better defined, and a coherent rim forms at the periphery of the lesion. This correlates with the zone of granulation tissue and inflammatory cells on histopathology in animal models [10]. Between 1 and 3 months the ablation zone becomes progressively denser often forming a solid, homogeneous mass. Subsequently, this solid lesion involutes, and the overall lesion size should progressively diminish and should be complete absence of enhancement within the ablation zone after 3 months [10]. We observed this in our 19-year-old and 17-year-old patients. This should not be misinterpreted as evidence of an active tumor.

The development of air-lucencies and frank cavitation is common, with reported incidences of 24-31% [12]. These are more likely to occur where the ablation is close to a segmental bronchus, therefore in centrally located lesions, and when ablation zone is more than twice the size of the original tumor. A cavitation with linear scar formation was observed in the 36-year-old patient in our series, and exhibited a significant regression of the left upper lobe metastatic nodule.

In our series, we had complete response in two patients and significant regression of the metastatic nodule in one of the patients. There was no recurrence of the nodules at the 12-month follow-ups. The therapy was therefore of significant benefit to our nonsurgical candidates.

In conclusion, CT-guided percutaneous radiofrequency ablation is a feasible, relatively safe and effective therapeutic option for the treatment of unresectable lung metastases in high-risk patients. The clinical impact and long-term results of radiofrequency ablation need to be confirmed in a larger series of patients. Properly designed randomized multicenter trials should be the goal for incorporation of radiofrequency ablation of lung metastases into the arsenal of cancer treatment.

REFERENCES

電腦斷層導引經皮射頻燒融術治療肺轉移惡性腫瘤——對不適合外科手術治療的病人的經驗及結果

陳肇長1,5  劉會平2  朱昭穎3  陳子平4,5

長庚紀念醫院基隆院區 影像診療科1  胸腔外科4
中國南京明基醫學中心 胸腔外科2
香港中文大學 放射診斷系3
長庚大學 醫學院5

本論文的重點是為不適合手術治療的肺轉移惡性腫瘤的病人，利用電腦斷層導引經皮進行射頻燒融術的治療經驗及結果。三位女性病人，均為重覆復發性肺轉移的病患。腫瘤的位置，分別在肺頂端，心臟後端及肋膜。在局部麻醉下，使用電腦斷層導引經皮射頻燒融術治療。三病例均沒有出現嚴重的併發症，而在治療後每三個月進行電腦斷層追蹤治療效果。三病例的肺腫瘤都得到有效的控制。因此，電腦斷層導引經皮射頻燒融術，對不適合手術治療的肺轉移惡性腫瘤的病人，是一種低侵犯性及有效療法。