# CLINICAL APPLICATION AND ADVANCES IN RADIOFREQUENCY ABLATION OF LUNG NEOPLASMS

*Essay*

Submitted for Fulfillment of Master Degree in Radiodiagnosis

*By*

***Farida Mohamed Metwali***

*M.B, B. Ch*

*Supervised By*

Dr. Naglaa Mohamed Abdel-Razek

*Assistant Professor of Radiology,*

*Faculty of Medicine - Cairo University*

Dr. Ahmed El Halafawy

*Assistant Professor of Chest Diseases*

*Faculty of Medicine - Cairo University*

Dr. Eman Mohamed Hamdy

*Lecturer of Radiology*

*Faculty of Medicine - Cairo University*

***Faculty of Medicine***

***Cairo University***

***2012***

## Abstract

Chest wall involvement by either primary lung cancer or metastatic deposits is common. Large chest wall tumors are difficult to treat with radiation therapy alone, and many patients with intractable pain have already received the maximal dose of radiation.



- Key word: RFA- *Technical*- Epidemiology-sonographic- *MHZ*

# Acknowledgement

First of all, I thank Allah who gave me

the power to finish this work.

I would like to express my deepest gratitude and cardinal appreciation:

*To* Prof. Dr. Naglaa Mohammed Abdelrazek, *Assistant professor of radio diagnosis, Faculty of Medicine, Cairo University, for her kind Guidance and supervision.*

*To* Dr. Ahmed Elhalafawy *Assistant Professor of Chest Disease, Faculty of Medicine, Cairo University.*

*Thanks to* Dr. Eman Mohammed Hamdy *lecturer of radio- diagnosis, Faculty of Medicine, Cairo University, for her supervision and participation in this work.*

*Finally I am thankful to my family who support me throughout the work.*

Farida Mohammed

# List of Contents

| Title | Page No. |
|---|---|


*List of Figures* ........................................................................................................ *I*
*List of Tables* ........................................................................................................ *V*
*List of Abbreviations* ................................................................................ *VI*
*Introduction*.................................................................... *1*
*Aim of the Work*........................................................... *3*
*Review of Literature*
*US & CT Radiological Anatomy and Techniques* *Error! Bookmark not defined.4*

- Normal sonographic anatomy
- Computed tomography anatomy

*Pathology and Radiological Findings*.............................................................. *25*

- Primary lung cancer
- Incidence &prevalence
- Epidemiology
- Pathology
- Staging

*Physical and Technical Principles* ........................................................... *40*

- Technical principle
- Available devices
- Patient selection
  - *Non small cell lung cancer*
  - *Pulmonary metastasis*
- Technique in details
  - *Pre procedure preparation*
  - *Anesthesiology care*
  - *Imaging Guidance and monitoring*
  - *Post-procedure management*
  - *Complications*
- Assessment of treatment response
- Outcome in other studies

*Illustrative Cases*............................................................................ *87*
*Summary and Conclusion*........................................................... *98*
*References* ...................................................................................... *100*
*Arabic Summary*

# List of Figures


| Table No. | Title | Page No. |
|---|---|---|
| **Fig. (1):** | Examination of the seated patient | 5 |
| **Fig. (2):** | Examination of the seated patient | 6 |
| **Fig. (3):** | Trans hepatic examination | 6 |
| **Fig. (4):** | Examination from the lateral aspect | 7 |
| **Fig. (5):** | Chest wall with normal smooth visceral pleura | 8 |
| **Fig. (6):** | Clearly recognizable double contour in the area of the parietal pleura | 9 |
| **Fig. (7):** | Numerous comet-trail artifacts on the diaphragmatic pleura | 9 |
| **Fig. (8):** | Transverse sonogram shows a biopsy needle | 14 |
| **Fig. (9):** | CT mediastinal window | 16 |
| **Fig. (10):** | A) Segmental bronchi, B) Schematic drawings of segmental lung anatomy at representative level | 21 |
| **Fig. (11):** | Vascular anatomy of pulmonary hila. | 24 |
| **Fig. (12):** | Bronchogenic carcinoma. | 28 |
| **Fig. (13):** | Solitary bronchoalveolar cell carcinomas | 29 |
| **Fig. (14):** | Computed tomography shows a mass (m) in the left upper lobe | 29 |
| **Fig. (15):** | Mixed well differentiated adenocarcinoma/ bronchoalveolar cell carcinomas | 30 |
| **Fig. (16):** | Calcified bronchial carcinoids. | 31 |
| **Fig. (17):** | Separate tumor nodules. | 32 |
| **Fig. (18):** | Chart illustrates the descriptors from the 7th edition of the TNMstaging system for lung cancer | 34 |
| **Fig. (19):** | Stage T1 tumors. (a) Chest CT scan shows a left lower lobe nodule (arrow) measuring less than 2 cm in size, a finding that is consistent with a stage T1a tumor (≤2 cm). (b) Chest CT scan obtained in a different patient shows a right upper lobe nodule (arrow) measuring 2.9 cm in size, a finding that is consistent with a stage T1b tumor (>2 cm but ≤3 cm). | 34 |
| **Fig. (20):** | Stage T2 tumors. (a) Chest CT scan shows a centrally located lung nodule (arrow) causing airway obstruction, with atelectasis or postobstructive pneumonia that does not, however, involve the entire lung. (b) Chest CT scan obtained in a different patient shows a mass in the right lung (arrow) measuring 4.8 cm, a finding that is consistent with a stage T2a tumor (>3 cm but ≤5 cm). (c) Coronal chest CT scan obtained in a third patient shows a nodule in the bronchus intermedius (arrow). The nodule is 4 cm from the carina (an endobronchial lesion > 2 cm from the carina is considered stage T2). At histopathologic analysis, the nodule proved to be a squamous cell carcinoma. | 35 |
| **Fig. (21):** | Stage T3 tumors. (a) Chest CT scan shows an irregular mass in the left upper lobe with suspicious local extension to the mediastinal pleura (arrow), a finding that was subsequently confirmed at surgery and histopathologic analysis. (b) Chest CT | |

scan obtained in a different patient shows an endobronchial mass (arrow) less than 2 cm from the carina. Pathologic analysis confirmed malignant carcinoid tumor, which can be staged using the 7th edition of the TNM staging system. (c) Chest CT scan obtained in a third patient shows a left lower lobe mass over 7 cm in diameter (arrow). ). ........................................................................ 36

**Fig. (22):** Stage T3 tumors. Chest CT scan shows a primary mass (arrow) with satellite nodules (arrowheads) in the right lower lobe. This is considered stage T3 disease in the 7th edition (stage T4 disease in the 6th edition) ........................................................................ 36

**Fig. (23):** Stage T4 tumors. Chest CT scan shows a primary lung tumor in the right upper lobe (long arrow) with a smaller separate nodule in the right lower lobe (short arrow). In the 7th edition, this is considered stage T4 disease (stage M1 [metastatic] disease in the 6th edition))........................................................................ 37

**Fig. (24):** Stage T4 tumors. Chest CT scan shows a right upper lobe mass (arrow) with mediastinal and carinal invasion, ipsilateral loculated pleural effusion, and thickening and enhancement of the pleura. Note the tumor encasement and resultant narrowing of the right main-stem bronchus (arrowhead). The pleural thickening and enhancement, although nonspecific, are suggestive of metastatic pleural disease. In the 7th edition, proved pleural carcinomatosis is considered stage M1a disease (stage T4 in the 6th edition)........................................................................ 37

**Fig. (25):** Stage N1 lymph nodes. **(a)** Chest CT scan obtained in a patient with right-sided lung cancer shows an enlarged right hilar lymph node (level 10) (arrow) measuring 15 mm in the short axis. (b) Chest CT scan obtained in a different patient shows a left lower lobe mass and an ipsilateral enlarged interlobar lymph node (level 11) (arrow) measuring 11 mm in the short axis............................ 38

**Fig. (26):** Stage N2 lymph nodes. (a) Chest CT scan shows an enlarged (1.6-cm) right upper paratracheal lymph node (level 2) (arrowhead). (b) Chest CT scan obtained in a different patient shows an enlarged (1.5-cm) right lower paratracheal lymph node (level 4) (arrowhead). Like the lymph node in a, it is clearly to the right of the new border proposed by the IASLC (ie, the left lateral border of the trachea). (c) Chest CT scan obtained in a third patient shows a right lower lobe mass (white arrow) with an enlarged (1.6-cm) subcarinal lymph node (level 7) (black arrow)........................................................................ 38

**Fig. (27):** Stage N3 lymph nodes. (a) Axial PET/CT image of the chest shows a primary mass in the left lung (arrow) and a right lower paratracheal lymph node (arrowhead), both of which demonstrate intense radiotracer uptake. Metastatic involvement of the lymph node was confirmed at mediastinoscopic resection. (b) Chest CT scan obtained at the lung apex in a different patient

shows enlarged bilateral supraclavicular lymph nodes (arrows). Metastatic involvement was confirmed at excisional biopsy .................. 39
**Fig. (28):** Schematic shows ionic agitation by alternating electric currents. The tissue ions are agitated as they attempt to follow the changes in direction of alternating electric current. The agitation results in frictional heat around the electrode .................................................... 41
**Fig. (29):** Various radiofrequency (RF) electrodes: a single needle design (Cool Tip, Valley lab System, and Tyco), b cluster electrode (Cool Tip Cluster, Valley lab, Tyco); multi-tined electrodes (c LeVeen, Radio therapeutics, Boston Scientific c; d Starburst XL; e perfused Talon needle, Angio Dynamics-RITA); f internally cooled, bipolar single needle electrode.................................................... 45
**Fig. (30):** Multitined expandable probe .................................................................. 46
**Fig. (31):** Valley Lab Cool-Tip cluster probe ......................................................... 46
**Fig. (32):** CT and gross pathologic appearances of ablated metastasis. .................. 52
**Fig. (33):** Sequential computed tomography (CT) fluoroscopy images obtained during the creation of artificial pneumothorax ......................... 59
**Fig. (34):** CT suite during lung RFA. ...................................................................... 61
**Fig. (35):** (a) CT scan showing a biopsy proven recurrent squamous cell cancer post radiotherapy in the left upper lobe (LUL). (b) Electrode deployed to 4 cm. (c) Immediate post-ablative CT scan showing bubbles within the ablated tumor and an area of GGO surrounding the tumor. (d) CT scan 3 weeks post ablation shows a large cavity at the treatment site with an air-fluid level. (e) CT scan showing an inserted drain through which 250 ml of frank pus were drained.......................................................................... 63
**Fig. (36):** CT image shows a patient undergoing radiofrequency ablation. The tip of the device is inside the lesion................................................. 64
**Fig. (37):** CT image of the same patient shown in Fig.36, at pulmonary window setting. The ablated lesion is surrounded by ground-glass opacification, and this represents an optimal result immediately after radiofrequency ablation ............................................ 64
**Fig. (38):** CT image of the ablated lesion of the patient shown in Fig 31, at mediastinal indow setting. The lesion is totally necrotized immediately after the radiofrequency ablation ...................................... 65
**Fig. (39):** CT image obtained 6 months after radiofrequency ablation. The ablated lesion of the patient shown in Fig.31 appears hypo dense, unenhanced and decreased in size. These findings indicate complete ablation ...................................................................... 65
**Fig. (40):** CT image obtained 6 months after radiofrequency ablation. These findings indicate complete ablation............................................. 66
**Fig. (41):** Contrast enhanced follow-up CT image at one year reveals local Recurrence of the lesion ........................................................................ 66
**Fig. (42):** Left upper lobe (LUL) tumor treated with RFA. A: Pre-RFA chest CT scan demonstrating LUL speculated 3.3-cm mass. B: Intraoperative image of RFA electrode impaling the tumor via a percutaneous approach. C: CT scan 5 months after RFA. Note

the central hypo attenuation and decreased density of the lesion. D: PET scan 5 months after RFA demonstrates LULn (arrow). ............. 67

**Fig. (43):** (A) CT scan showing radiofrequency ablation of right lower lobe colorectal metastasis. (B) Follow-up CT scan 2 months post ablation demonstrates a large cavitary lesion at the site of ablation. The patient was asymptomatic and no additional interventions were performed ............................................................. 68

**Fig. (44):** (A) CT scan showing biopsy-proven left upper lobe metastasis from colon cancer. (B) Radiofrequency ablation of the lesion with adjacent parenchymal hemorrhage and ground glass changes. (C) Follow-up CT scan 1 month post ablation demonstrates an enlarged ablation zone that gradually regresses at the 6-month follow up CT scan (D) and at the 1-year follow-up study (E).......................................................................... 69

**Fig. (45):** (A) Radiofrequency ablation of biopsy-proven right upper lobe NSCLC. (B) Immediate post-procedural pneumothorax seen on CT scan. (C) Chest x-ray demonstrating residual pneumothorax and subcutaneous emphysema following chest tube insertion ................ 76

**Fig. (46):** (A) Radiofrequency ablation of two pulmonary metastases in the left upper lobe. Parenchymal hemorrhage is seen anterior to the more posterior lesion but did not preclude radiofrequency probe insertion. (B) Pulmonary hemorrhage in the left upper lobe seen immediately following ablation. (C) Follow-up CT scan 2months after ablation demonstrates interval resolution of the parenchymal hemorrhage....................................................................... 77

**Fig. (47):** Case 1.......................................................................................... 88

**Fig. (48):** Case 2 .......................................................................................... 90

**Fig. (49):** Case 3 .......................................................................................... 94

**Fig. (50):** Case 4 .......................................................................................... 96

**Fig. (51):** Case 5.......................................................................................... 97

**Fig. (52):** Case 6…………………………………………………………………97

# List of Tables


| Fig. No. | Title | Page No. |
|---|---|---|
| **Table (1):** | The non-small cell type is the most prevalent by far | 27 |
| **Table (2):** | Selection Criteria to determine When to Use RFA | 49 |
| **Table (3):** | Modified RECIST Criteria LD, largest diameter of lesion; FDG, fluorodeoxyglucose; SUV, standardized uptake value of fluorodeoxyglucose. A Standard uptake value of 18-FDG on PE scan | 80 |
| **Table (4):** | Studies reporting survival outcomes of patients with stage INSCLC who underwent percutaneous RF ablation | 82 |
| **Table (5):** | Studies reporting survival outcomes of patients with colorectal cancer lung metastases who underwent percutaneous RF ablation | 84 |

# List of Abbreviations

| | |
|---|---|
| ***3D*** | ***: Three dimention*** |
| ***COPD*** | ***: Chronic obstructive pulmonary disease*** |
| ***CM*** | ***: Centimeter*** |
| ***CT*** | ***: Computed Tomography.*** |
| ***FDA*** | ***: food &drug administration*** |
| ***GGO*** | ***: Ground glass opacification .*** |
| ***H*** | ***: Hounsefeild unit*** |
| ***mA*** | ***: Milliamber*** |
| ***MHZ*** | ***: Mega hertz.*** |
| ***mm*** | ***: Milli-meter.*** |
| ***MRI*** | ***: Magnetic resonance imaging*** |
| ***RF*** | ***: Radiofrequency*** |
| ***RF A*** | ***: Radiofrequency ablation*** |

# INTRODUCTION

Lung cancer kills more patients each year than breast, colon and prostate cancer combined ***(Terrance et al., 2011).***

Patients with advanced non-small cell lung carcinoma (NSCLC) have a median survival time of 6–8 months and a 1-year survival rate of only 10–20% ***(Kelekis et al., 2006).***

Surgical resection remains the treatment of choice for patients with early-stage non small cell lung cancer. However, some patients are not surgical candidates because of medical problems. Therefore, alternative therapies are considered in these medically inoperable patients. Radiofrequency ablation has been used clinically for more than 12 years, with many studies reporting its safety and efficacy ***(Terrance et al., 2011).***

RF ablation is becoming a viable option for the treatment of metastatic disease of the lung ***(Scheneider et al., 2009).***

The effectiveness of radical Radiotherapy for stage I/II medically inoperable NSCLC patients, overall five-year survival ranged 0–42% ***(Rowell et al., 2003).***

The role of chemotherapy in NSCLC has primarily been for patients with more advanced disease alone or in conjunction with radiotherapy ***(Strauss et al., 2004).***

RFA of lung malignancies is performed with two basic rationales in the first group it is used with an intention of achieving definitive therapy, in the second group it is used as a palliative measure ***(Dupuy et al., 2000).***

Underlying principle of thermal ablation is that coagulative necrosis and cell death occur immediately at temperatures greater than 60-C. In clinical practice, RFA of lung tumors routinely achieves temperatures greater than 70-C ***(Terrance et al., 2011)***.

Multiple imaging techniques [ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET)] have been used to guide the percutaneous placement of the RF energy applicators. For lung lesions, CT and MRI are the only modalities that can be used ***(Kelekis et al., 2006).***

RF ablation is becoming a viable option for the treatment of metastatic disease to the lungs. After ablation, histology shows typical zones of thermal damage, radiating away from the central heat source ***(Jaskolka et al., 2010)***.

An artificial pneumothorax was assumed to be effective for pain relief in RF of peripherally subpleural tumors ***(Lee et al., 2007).***

Intra-parenchymal hemorrhage typically resolves without intervention; however, Proper patient selection for ablation therapy, by means of excluding all possible causes of coagulopathy, and a refined technique of avoiding traversing pulmonary vasculature in the ablation track, can prevent catastrophic results ***(Nour-Eldin et al., 2011).***

Re-RF ablation for lung tumors was completed successfully without any major complications. However, re-RF ablation for unresectable lung tumors previously treated with RF ablation showed a high rate of local progression ***(Okuma et al., 2008)***.

# AIM OF THE WORK

The purpose of the essay is to review the principles of radiofrequency ablation, its clinical application and role in the management of primary and metastatic lung tumors.

# US & CT Radiological Anatomy and Techniques

## i. Normal Sonographic Anatomy:

Ultrasound is a reliable and efficient imaging method to evaluate a wide range of clinical problems in the chest and to guide diagnostic and therapeutic procedures. Although the ribs, spine, and air filled lung act as barriers to ultrasound visualization of intrathoracic diseases, the presence of fluid in the pleural space and tumor, consolidation, or atelectasis in the lung provide ample sonographic windows for evaluation ***(McLoud et al., 1991).***

Up to 99% of the ultrasound wave is reflected in the healthy lung. Intrapulmonary processes can be detected by sonography only when they extend up to the visceral pleura or can be imaged through a sound-conducting medium such as fluid or consolidated lung tissue ***(Beckh et al., 2002).***

A high-resolution linear transducer of 5–10 MHz is suitable for imaging the thoracic wall and the parietal pleura ***(Mathis et al., 2007).***

More recently introduced probes of 10–13 MHz are excellent for evaluating lymph nodes, pleura and the surface of the lung ***(Gritzmann et al., 2005).***

For investigation of the lung a convex or sector probe of 7–10 MHz provides adequate depth of penetration. The investigation is performed as far as possible with the patient seated, during inspiration and expiration, if necessary in combination with respiratory maneuvers such as coughing or “sniffing.” Raising the arms and crossing them behind the head causes intercostal spaces to be extended and facilitates access. The transducer is moved from ventral to dorsal along the longitudinal lines in the thorax ***(Mathis et al., 2007)***. ***(*****Fig.1*****)***.

- Parasternal line.
- Mid clavicular line.
- Anterior, middle and posterior axillary line.
- Lateral and medial scapular line.
- Para vertebral line ***(Mathis et al., 2007)***.***(*****Fig 1*****)***

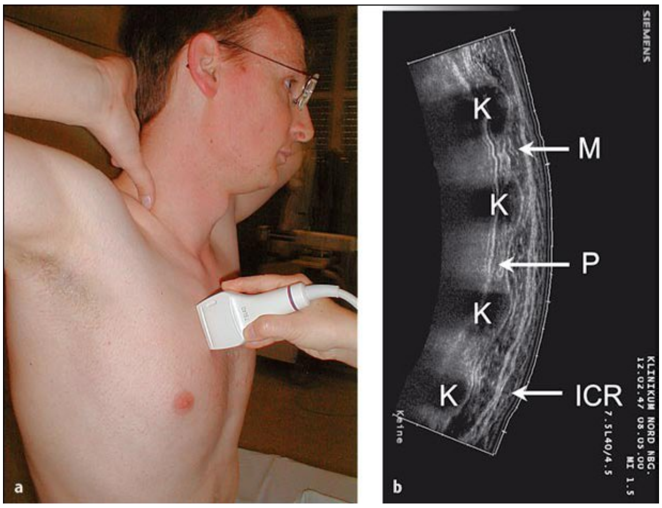


**Fig. *(*1*)*: Examination of the seated patient *(*a*)*** Linear probe placed longitudinally on the right parasternal line. ***(*b*)*** Corresponding sonographic longitudinal panoramic image. **K** cartilage at the point of insertion of the rib, **ICR** intercostal space, **M** muscle, **P** line of the pleura ***(Mathis et al., 2007).***

Subsequent transverse transducer movement parallel to the ribs in the intercostal space provides the additional information required for accurate localization of the respective finding ***(Mathis et al., 2007)*** (**Fig. 2**).