THE ROLE OF PERCUTANEOUS CT GUIDED RADIOFREQUENCY ABLATION IN THE TREATMENT OF PRIMARY AND SECONDRY LUNG MALIGNANCIES

THESIS

Submitted for partial fulfillment of the master degree in radio-diagnosis

By

Ahmed Hamdy Abd El Ghany Heussein

M.B.B.Ch.
Faculty of medicine
Cairo University

Under Supervision of

Ass. Prof. Dr. Ayman Ismail Kamel
Assistant professor of radio-diagnosis
Faculty of medicine
Cairo University

Dr.Mohamed Hamed Shaaban
Lecturer of radio-diagnosis
Faculty of medicine
Cairo University

2012

بسم الله الرحمن الرحيم

“Hippocrates is reported as saying that those diseases that medicine cannot cure, the knife cures; those which the knife cannot cure, fire cures” (Adams 1886).

Acknowledgement

Thanks to "ALLAH" the Gracious and the Merciful who guided me to the straight path and paved the way for all my efforts.

I would like to express my deep appreciation and cordial regards to ***Prof. Dr Ayman Ismail Kamel,*** *Assistant Professor of Diagnostic and Interventional Radiology, Cairo University, for his great help, sincere effort, and valuable directions during the conduct of this work.*

I would like to express my deep gratitude and sincere thanks to ***Dr. Mohamed Hamed Abd Al Fattah Shaaban,*** *lecturer of Diagnostic and Interventional Radiology, Cairo University, who supervised this work. Indeed, it has been a privilege for me that he guided me throughout this work.*

My deepest thanks and appreciation also belong to my entire colleagues, in the Diagnostic and Interventional Radiology Departments, in Cairo University for their help and contribution.

Especially, I would like to give my cordial thanks to my parents and brothers for their care and support that enabled me to complete this work.

ABSTRACT

Ablation of lung tumors is an expanding area within interventional oncology. Radiofrequency ablation is especially among the most widely used of these thermal ablation methods. Which of these ablation technologies becomes the preferred technique for lung tumors remains to be seen. Evidence based research studies concluded that the safety profile was sufficiently well understood for ablation to be performed but that its role relative to other treatment modalities is still unclear.

The efficacy of RF ablation therapy of pulmonary neoplasms is mainly determined by pre-ablation tumor size and location in relation to the hilum. Successful ablation of pulmonary metastases is more likely for peripheral lesions of < 3cm. The preablation tumor size (of < 3cm) is the most significant independent predictor of ablation success. Careful selection of cases where the benefit of ablation therapy will outweigh the potential complications is key to ensure optimal patient outcomes.

Keywords:

Lung tumors, radiofrequency ablation, metastases, RFA, minimally invasive techniques.

List of Contents

	Page
Introduction	1
Anatomy of the lung	3
Pathology of lung cancer	16
Imaging of lung cancer	26
Treatment options for pulmonary neoplasms	38
Physical principles of radiofrequency ablation	45
Patient selection, technique and complications	57
Patients and methods	77
Results	90
Case presentations	93
Discussion	104
Summary and conclusion	119
References	122
Arabic summary	

List of tables

		Page
Table (1):	shows the WHO histological classification of malignant lung tumors	19
Table (2):	the new staging system for lung cancer	22
Table (3):	Results of surgical resection for lung cancer in 11 studies	40
Table (4):	Modalities Used to Determine Therapeutic Response after RFA	73

List of figures

		Page
Fig. (1,2):	lobar anatomy of the lung	3
Fig. (3):	the trachea-bronchial tree	6
Fig. (4-6):	axial CT cuts of the segmental branches of the right main bronchus	7
Fig. (7-9):	axial CT cuts of the segmental branches of the left main bronchus	8
Fig. (10-15):	axial CT cuts showing the anatomy of the mediastinum	11
Fig. (16):	microscopic picture of lung adenocarcinoma	20
Fig. (17):	microscopic picture of small cell carcinoma	21
Fig. (18,9):	Adenocarcinoma presenting as a peripheral SPN (left), and as a central mass with bronchial obstruction and obstructive atelectasis (right)	27
Fig. (20):	chest wall invasion with rib erosion in a pathologically proven Adenocarcinoma	31
Fig. (21):	non-uniform pleural thickening from bronchogenic tumor extension	33
Fig. (22):	T2WI in bronchogenic cancer patient with bilateral pleural effusions	34
Fig. (23):	mediastinal lymphadenopathy in metastatic bronchogenic carcinoma	34
Fig. (24):	a) Schematic and (b) gross specimen show focal thermal ablation	47
Fig. (25):	interdependency of temperature and radius around a single needle	48
Fig. (26):	method for combining thermal ablation with targeted drug delivery	51
Fig. (27):	LeVeen CoAccess Electrode System	53
Fig. (28):	Images of various commonly used and commercially available RF electrode designs	55
Fig. (29):	RF 3000 Radiofrequency Ablation System	56
Fig. (30):	CT suite during lung RFA	62
Fig. (31):	Grounding pads properly attached to the patient's thighs, equidistant to the RF site	63
Fig. (32):	Right) CT image shows 1.5 cm metastasis in the lower lobe. (Left) CT image obtained during percutaneous radiofrequency ablation under CT fluoroscopy guidance with patient in prone position shows electrodes deployed to 2 cm	65
Fig. (33):	how to try to spike a tumor bouncing off needle tip	67
Fig. (34):	(a) Electrode deployed to 4 cm. (b) Immediate post-ablative CT scan showing bubbles within the ablated tumour and an area of GGO surrounding the tumor	70
Fig. (35):	(a) a hyperdense mass representing a right lower lobe nonsmall cell lung cancer. (b) After radiofrequency thermal ablation, the	70

	tumor mass is surrounded by a ground-glass halo. (c) The tumour mass is no longer visible 3-yrs later and a thin hyperdense fibrotic scar is present at the site of the tumor	
Fig. (36):	(a) CT image shows 1.5 cm metastasis in the lower lobe. (b) Control CT scan obtained at 1 week post RFA shows initial increase of ablated area. c–e, Control CT scans obtained at 1 month (c), 3 months(d), and 6 months (e) show initial increase of ablated area (c), followed by gradual shrinking (d and e)	72
Fig. (37):	A 79-year-old man with a pulmonary metastatic lesion in the left upper lobe (a–c) before and (d–f) after (RFA)	76
Fig. (38):	A pie chart showing the selected cases	77
Fig. (39):	Algorithm of management of pneumothorax developing before the termination of the ablation	85
Fig. (40):	Algorithm of management of pneumothorax developing before the termination of the ablation	86
Fig. (41):	Box-Plots Diagram illustrates the volumetric changes post RFA in all lesions involved in the study (the vertical axis in cc). Preablation volumes as well as the24h, 4-6w, 3m post ablation are illustrated	91
Fig. (42):	Case1	93,94
Fig. (43):	Case 2	95
Fig. (44):	Case 3	96
Fig. (45):	Case 4	97,98
Fig. (46):	Case 5	99,100
Fig. (47):	Case 6	101
Fig. (48):	Case 7	102,103

List of Abbreviations

AAH	Atypical adenomatous hyperplasia
BAC	Bronchoalveolar cell carcinoma
BAL	Bronchoalveolar lavage
BSC	Best supportive care
CMT	Chemotherapy
CR	Complete response
CT	Computer Tomography
CXR	Chest X ray
DIPNECH	Diffuse idiopathic neuroendocrine cell hyperplasia
FB	Fiberoptic Bronchoscopy
FDG-PET	18Fluro-2deoxy-D-Glucose Positron Emission Tomography
HIFU	High Intensity Focused Ultrasound
INR	International Normalized Ratio
IRE	Irreversible Electroporation
ISSLC	International Staging System for Lung Cancer
KV	Kilo Volt
LCNEC	Large cell neuroendocrine cancer
LITT	Laser induced Interstitial Thermotherapy
mAs	Milliamper second
MRI	Magnetic Resonance Imaging
MW	Microwave
MWA	Microwave Ablation
NSCLC	Non Small Cell Lung Cancer
PC	Prothrombin Concentration
PET-CT	Positron Emission Tomography-Computer Tomography
PR	Partial Response
PT	Prothrombin Time
PTT	Partial Thromboplastin Time
r	Radius
RF	Radiofrequency
RFA	Radiofrequency Ablation
RT	Radiotherapy
SCC	Squamous cell carcinoma
SCLC	Small Cell Lung Cancer
SPN	Solitary pulmonary Nodule
T	Temperature
TNA	Transthoracic Needle Aspiration
TNB	Transbronchial Needle Biopsy

VATS	video-assisted thoracic surgery
WHO	World Health Organization

INTRODUCTION

Primary lung cancer is a severe worldwide health problem causing a greater death than breast, prostate, and colorectal cancer combined **(Brescia, 2001)**.

Surgical resection is the treatment of choice for primary nonsmall cell lung cancers (NSCLCs) and isolated pulmonary metastases from colorectal cancer. However, approximately two-thirds of all NSCLC patients are ineligible for curative resection due to tobacco-related comorbidity, concomitant extrapulmonary diseases and/or advanced age. Surgery is excluded in a similar percentage of pulmonary metastases patients due to the presence of multifocal disease. In any case, the surgical approach is by no means free from complications, including mortality, and it is difficult to repeat for recurrences **(Licker et al., 2002)**.

Systemic chemotherapy and radiation therapy are often the only options offered to lung cancer patients, but these approaches produce substantial increases in survival only in small subsets of highly selected cases **(Rossi et al., 2006).**

As compared to lung resection, local ablative methods bear indisputable advantages. The surgical trauma may contribute to recurrence, growth of metastases, and metastatic spread. These unwanted consequences of surgery depend on factors such as immunosuppression **(Colacchio et al. 1994)**, shedding of tumor cells into the wounded area and the circulation as well as the production and release of growth factors for wound healing, which influence tumor cell adhesion and growth **(Brown et al. 1999).**

The term tumor ablation is defined as the direct application of chemical or thermal therapies to a specific focal tumor in an attempt to achieve eradication or substantial tumor destruction. The term "direct" aims to distinguish these therapies from others that are applied orally or via an intravascular or peripheral venous route. Different modalities are used for tumor thermal ablation including radiofrequency, microwave, laser, high intensity focused ultrasound and cryoablation **(Goldberg et al., 2003)**.

Percutaneous radiofrequency thermal ablation (RFA) under CT guidance is a minimal invasive technique that is used over a decade for the treatment of primary and secondary liver tumors. It is a low cost method that provides treatment on an outpatient basis and has low complication rates in experienced hands. RFA under CT guidance without thoracotomy may be considered an interesting alternative of local treatment in inoperable cases of primary and metastatic lung tumors. (**Thanos et al., 2006)**.

Early clinical experiences with RFA suggest that it could serve as a potential addition (or alternative) to surgery and radiation therapy for the local treatment of primary and secondary malignant lung tumors. Major complications are rare, with post procedural fever, pain, and pneumothorax being most commonly reported **(Nguyen et al., 2006)**.

ANATOMY

1. PLAIN RADIOGRAPHY

The Central Airways

The trachea is directed downward and backward in the midline in children and young adults. It deviates to the right in older subjects with aortal unfolding and ectasia and may also bow forward. In cross-section the trachea is usually round, oval, or oval with a flattened posterior margin. The upper limits of normal coronal and sagittal diameters in adults on plain chest radiography are 21 and 23 mm, respectively, for females, and 25 and 27 mm for males (Breatnach et al 1984).

Calcification of the cartilage rings of the trachea is a common normal finding after the age of 40 years, increasing in frequency with age. The trachea divides into the two mainstem bronchi at the carina. In children the angles are symmetrical, but in adults the right mainstem bronchus has a steeper angle than the left. The left main bronchus extends up to twice as far as the right main bronchus before giving off its upper lobe division

1.2. Lobar Anatomy

Each lung is divided into lobes surrounded by pleura. There are two lobes on the left: the upper and lower, separated by the major (oblique) fissure, and three on the right: the upper, middle and lower lobes separated by the major (oblique) and minor (horizontal) fissures. The fissures are frequently incomplete, containing localized defects which form an alveolar pathway for collateral air drift but also the spread of disease. For a fissure to be visualized on conventional radiographs, the X-ray beam has to be tangential to the fissure. In most people, some or the whole of the minor fissure is seen in the frontal projection, but neither major fissure can be identified. In the lateral view, both the major and minor fissures are often identified, but usually only part of any fissure is seen; in fact, it is very unusual to see both left and right major fissures in their entirety (Amstrong).

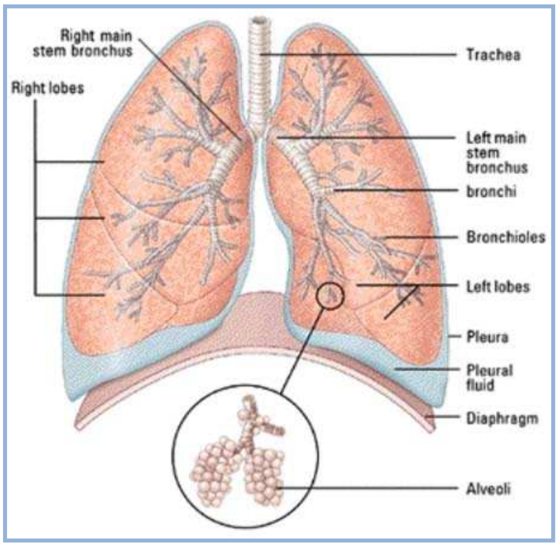

Fig 1

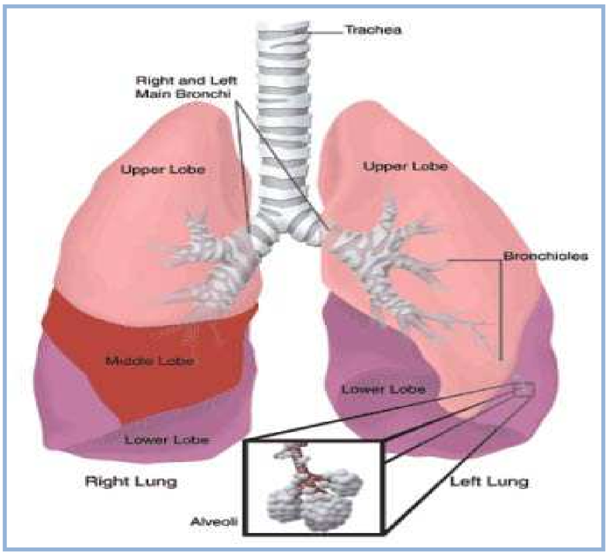

Fig 2

Figures 1, 2 Lobar Anatomy of the lungs (Gruden et al, 2000)

The major fissures have similar anatomy on the two sides. They run obliquely forwards and downwards from approximately the fifth thoracic vertebra to pass through the hilum and contact the diaphragm 0–3 cm behind the anterior costophrenic angle. Each major fissure follows a gently curving plane with the upper portion facing forward and laterally