recurrence following TA are common to all techniques, but some of those that did not enter clinical trials due to the disadvantage of long ablation times could help in particular clinical settings. Furthermore, newer techniques like microwave (MW) have intra-operative advantages over the older RF in terms of faster execution times clearly demonstrated in dose-response studies. [12-13-14].

2. Aim of the Work

The main purpose of this study is to compare the temperature distribution and tissue necrosis patterns for a hepatocellular carcinoma after radiofrequency ablation therapy.

3. Materials and Methods

1- Study Patients

A 20 patients were included in this study proved to have HCC and were treated by RFA alone or with combined therapies (RFA /TCAE/PEI), fulfilled the following inclusion criteria: Presence of a single up to 5 cm in diameter or multiple (maximum three) focal lesions of not exceeding 3 cm in diameter each, absence of extra hepatic spread, absence of vascular and biliary invasion, absence of portal vein thrombosis (main trunk or its branches) and absence of marked bleeding diathesis (Prothrombin concentration should be over 60% and platelet count not be less than 50,000), patients with hepatitis class A or B and those with class C must have less than moderate ascites.

2- Radiological Assessment

Two coincident imaging techniques (two techniques considered: ultrasound, spiral CT) Focal lesion up to 5 cm with arterial hypervascularization. One imaging technique associated to alpha-fetoprotein (AFP) for Focal lesion up to 5 cm with arterial hyper vascularization AFP levels >200 IU/ml. Cardiac and chest examination, ECG, blood pressure and Blood glucose level were done. A Computed Tomography CT (GE high speed model zx/i) abdomen was performed to all patients before and after the radiofrequency ablation treatment, for detection of the Hepatocellular carcinoma, the basic principle behind CT is that the internal structure of an object can be reconstructed from multiple projections of the object.

3- CT Abdomen Technique

Patient position: supine with arms at head level volume of investigation: from dome of the liver to the aortic bifurcation with Normal slice thickness: 7-10 mm; 4-5 mm for suspected small lesions, Inter – slice thickness/pitch = 1.2 – 2.0, Focal of view (FOV) adjusted to the largest abdominal diameter with no gantry tilt, tube current and exposure time product (mAs) should be as low as consistent with required image quality, windows width: 150-600 Hounsfield units (HU) and preventing movement artifacts by a standard breath hold technique using oral contrast media (barium meal) amount 800ml before one hour from the examination, 200 ml immediately before the examination and intravenous contrast media (ultra vest) amount between 80 and 120 ml based on patient size and indication. Dynamic studies included acquisition of unenhanced images followed by acquisition of enhanced images in the hepatic arterial, portal venous, and delayed phases. Computer-assisted bolus-tracking software was used to determine the optimal scan delay for each patient. Acquisition of arterial phase images started 12 seconds after the automatic detection of aortic peak enhancement (120 H). The portal and late venous phases started 55 and 120 seconds after aortic peak enhancement.

4- Radiofrequency system

It is consists of a cool-tip RF generator, RF electrode (valleylab), grounding pads, perfusion pump, IV bag contain sterile water for infusion, adaptor cable, inflow container and outflow container. The cool-tip RF generator is a microprocessor - based coagulator capable of supplying up to 200 watts of RF power, it also continuously measures and displays RF current (0-4000 mA), impedance (0-1000 ohm) and temperature (0-100 C̊).For tumors of diamter greater than 3-cm, electrode cluster (with individual electrodes spaced 5 mm apart and 2.0 cm of exposed metallic tip) was used. Single cool tip EF electrode is used for tumors less than 3-cm in diameter.

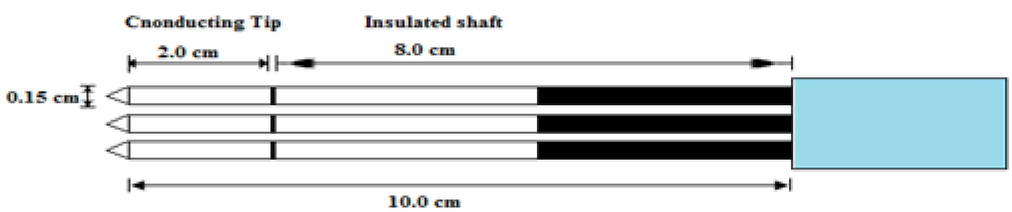

Figure 1: Ablation probe geometry diagram of a cluster needle ablation electrode that is used for hepatic therapeutic treatment

5- Radiofrequency Ablation Technique

Each application of RF energy lasted 12–15 minutes for tumors 2-3cm and 20-25 minutes for tumors up to 5cm; The RF electrodes were attached to a 500-kHz RF generator (Radionics) capable of producing 200 W of power. During the procedure, tissue impedance, RF watts, RF current was monitored by using circuitry incorporated within the generator. The skin is cleaned with providing iodine (Betadine) (which also served as a contact medium).Ultrasound guidance using a 3.5 MHz probe by free hand technique for lesions located in the right lobe, an intercostals approach with the patient in the left lateral decubitus position was generally performed, For lesions located in the left lobe, a sub costal approach was most often used. Ultrasound machine used in the present work and insertion of the RF electrode under the guidance of the ultrasound. The size of the tumors was initially measured by conventional US, planning a safety margin at least 5 cm of the surrounding tissue except in cases of HCC with poorly defined borders for which our goal was an ablation margin of 1.0 cm, Tumors larger than 3.5 cm in diameter were ablated with multiple overlapping spheres.

6- Thermal Mechanisms

The bioheat equation below was employed to analyze heat generation from electric energy. We solved the bioheat equation to obtain the thermal distribution in hepatic cancer tissue.

$$\rho c \frac{\partial T}{\partial t} = \nabla . \kappa \nabla T + J . E - h_{b1}(T - T_{b1}) - Q_m$$

(17)

ρ	=	Density$(\mathrm{kg/m^3})$
c	=	Specific heat (J/kg K)
k	=	Thermal conductivity (W/m·K)
J	=	Current density $(\mathrm{A/m^2})$
E	=	Electric field intensity (V/m)
T_{b1}	=	Temperature of the blood (assumed to be 37 °C)
ρ_{b1}	=	The blood density $(\mathrm{kg/m^3})$
c_{b1}	=	Specific heat of the blood(J/kg·K)
ω_{b1}	=	blood perfusion (1/s)
h_{b1}	=	The convective heat transfer coefficient accounting for blood perfusion in the model
Q_m		The energy generated by the metabolic processes $(\mathrm{W/m^3})$

For certain tumor size the time needed for the ablation of the tumor at 100°C was calculated. Also the temperature distribution around the electrode starting deeply from the electrode surface up to the tumor boundary was studied. The bioheat equation below was employed to analyze heat generation from electric energy. We solved the bioheat equation to obtain the thermal distribution in hepatic cancer tissue For certain tumor size the time needed for the ablation of the tumor at 100°C was calculated.

Also the temperature distribution around the electrode starting deeply from the electrode surface up to the tumor boundary was studied.

7 -Laboratory evaluation

For the determination of serum bilirubin, and albumin. All tests have been done in laboratories, also liver enzymes (SGPT and SGOT) were measured according to the method describes by [15] And HCV-RNA was detected using (RT-PCR).

8- Statistical Analysis

The local ethic committee approved this study .Informed consent was obtained from each patient included in this study .Data were expressed as mean + standard error (S.E).Data analysis was made by Fisher's exact and Pearson's correlation tests. Using SPSS for Widows (Chicago, II, USA) when appropriate $p < 0.05$ was considered statistically significant.

4. Results

1: Baseline Clinical characteristics and clinical courses of Patients

In this study, baseline characteristics of the 20 patients were summarized in (Table 1). The age of the patients ranged from 39 to 74 years and the mean age 56.5 years. As regards their sex, 13 were males (35%) and 7 were females (18.5%), the mean ALT activity measured before treatment were average of males group (50.16+ 12.8 S.D IU/L), and average of females group (58.37+12 S.D IU/L), mean AST measured before treatment were average of males group (46.9+19.1S.D IU/L), and average of females group (52.8+13.8S.D IU/L), The normal ranges for ALT and AST in males are (Up to 40 IU/L and Up to 37 IU/L, respectively) normal range for ALT and AST in females is (Up to 39 IU/L and Up to 36 IU/L, respectively). Mean albumin measured before treatment were average of males group (3.04+ 0.56 S.D g/L), and average of females group (2.7+0.35 S.D g/L), mean bilirubin measured before treatment were average of males group (1.4 + 0.61 S.D g/L), and average of females group (1.2+ 0.36 S.D g/L). The normal ranges for albumin and bilirubin in males were (3 - 5 g/L) and (0.2 - 1 g/L) respectively, normal range for albumin and bilirubin in females were (3 - 4.6 g/L) and (0.2 - 1 g/L), respectively. Mean HCV-RNA measured before treatment were average of males group (78.3 + 11.3 S.D copies /ml), and average of females group (84.5 + 6.35 S.D copies /ml). The normal ranges for HCV-RNA in males and females are (>2 x10^6 copies /ml).

Table 1: Baseline characteristics of study 20 patients

Parameter	*Male*	*Female*
SGPT Normal Range (mean+ S.D)	Up to 40 IU/L (50.1+12.8)	Up to 39IU/L (58.37+12.0)
SGOT Normal Range (mean+ S.D)	Up to 37 IU/ L (46.9+ 19.1)	Up to 36 IU/L (52.8+13.8)
Serum albumin Normal Range(mean+S.D)	3-5 g/L (3.04 + 0.56)	3-4.6g/L (2.7 + 0.35)
Serum bilirubin Normal Range (mean + S.D)	0.2-1 g/L (1.4 + 0.6)	0.2-1 g/L (1.2 + 0.36)
HCV-RNA > 2 million copies/ml (mean+ S.D)	(78.3+ 11.3) copies /ml	(84.5+ 6.35) copies /ml

The different statistical parameters including (Mean + S.D) with HCV F=female, M=male, S.D=Standard Deviation.

2- Effects of Radiofrequency Ablation on HCC

The temperature distribution of the radiofrequency at the electrode and tumor surfaces was calculated using estimated theoretical calculations.

Table (2): Temperature distribution C° at electrode surface after application of low radiofrequency powers (80: 150 watt) with mean= 130 ± Standard error= 2 and after application of high radiofrequency powers (145:186 watt) with mean= 160.1 ± Standard error = 2.6

RF Power (Watt)		*Tumor Radius (M)*	*Ablation Time (Min)*	*Temperature at Electrode Surface (C°)*	
Minim	*Max*			*At Min Power(watt)*	*At Max Power(watt)*
84	175	0.048	4	88.2599174	143.79149
135	180	0.048	6	158.33847	198.78463
140	184	0.048	5	142.817141	176.07396
123	165	0.0425	8	175.582674	222.90359
130	170	0.0425	9	199.526274	249.53436

Table (3): Shows the Temperature distribution C° at tumor surface after application of low radiofrequency powers (80: 150 watt) with mean= 113.7 ± Standard error= 1.7, and after application of high radiofrequency powers (145:186 watt) with mean= 138.2 ± Standard error = 2.2

Radiofrequency Power (Watt)		*Tumor Radius (M)*	*Ablation Time (Min)*	*Temperature at Tumor Surface*	
Min	*Max*			*At Min Power(watt)*	*at Max Power(watt)*
84	175	0.048	4	48.09452862	60.1136013
135	180	0.048	6	63.26210097	72.0161346
140	184	0.048	5	59.90271535	67.1007116
123	165	0.0425	8	80.21124807	94.9663084
130	170	0.0425	9	87.67706497	103.270008

Table (4): Shows the Minimum time required for ablation after application of fixed power (80watt and 186 watt) and different distances from the electrode tip (0.01:0.05 m)

Min RF Power (Watt)	*Max RF Power (Watt)*	*The distance from the center of the tumor(m)*	*Min time required for ablation (Sec)*	
			80 W	*186 W*
80	186	0.01	12.47556515	5.36267
80	186	0.015	42.20883758	18.11816
80	186	0.02	100.5332398	43.03545
80	186	0.025	197.9281811	84.34076
80	186	0.03	346.159968	146.4874
80	186	0.035	559.134935	234.2915
80	186	0.04	854.1587617	353.113
80	186	0.045	1253.851406	509.0962
80	186	0.048	1556.312834	623.4826

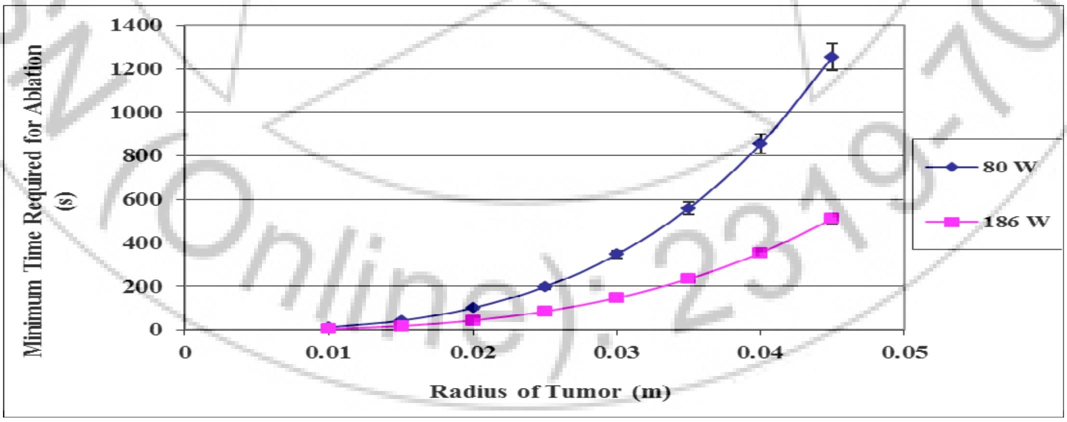

Figure (2): Effect of minimum time required for ablation (sec) on radius of the tumor (m)

5. Discussion

Radiofrequency ablation (RFA) is a local ablation technique designed to destroy the tumor by heating. Alternating current passing from an electrode into the surrounding tissue causes ions to vibrate and generate heat in the tissue. Increased current leads to more vigorous ionic motion and increased temperature over a period of time, eventually leading to coagulation necrosis and cell death. [18]

The evidence in the medical literature showed RFA was more effective than other local ablative therapies, and supported its use in the treatment of unrespectable small HCC, recurrent small HCC, and as bridging therapy before liver transplantation, and as a primary treatment in competition with partial hepatectomy for resectable small HCC. [19] In the present work we studied the effect of radiofrequency waves on hepatocellular carcinoma (HCC), by studying the effect of different radiofrequency powers (low and high powers) on the tumor temperature distribution around the RF insertion electrode.

In this work a mathematical studies have been performed to describe the rate of tumor temperature rising around the RF electrode and its effect on the tumor ablation. Our results showed that the ablation duration used in all cases ranging from 4-10 min. At low RF power, temperature varied from 88-223 °C and 60-225 while at high RF power, the temperature varied from 143-278 °C and from 140-179 °C at the electrode and tumor surface, consequently.Lesions continue to grow while temperature envelopes collapse after ablation since sufficiently high temperature is present to accrue tissue damage. In accordance to our results when the temperature of the electrode increases the tumor tissue was ablated and this was under ultrasound guidance and followed up with CT and alpha fetoprotein and a sudden increase in electrical impedance occurred. The efficacy of RFA can be assessed with contrast-enhanced ultrasound; contrast enhanced dynamic CT (CECT) or contrast-enhanced magnetic resonance imaging (MRI). A successful RFA treated area of HCC is nonenhancing on CECT and tends to be larger than the original tumor. [19] in this study we clarify the important role of contrast enhanced dynamic CT, all patients had pass through a routine CT abdomen with contrast and ultrasound examinations before and after treatment. The study was done under guidance of ultrasound. The texture of the tumor varied from before and after RF treatment this texture is monitored using abdominal CT with contrast before and after the treatment this variation in texture is caused because of that HCC is a malignant tumor which is supplied with blood vessels so when injecting the patient with contrast media before RF treatment the tumor appears a bright (hyper dense), but after Appling the RF treatment the texture appears to be black (hypodense), this means that the radiofrequency waves had applied the appropriate temperature to this tumor and destroyed all of its blood supplies. Also this is proved by laboratory investigation by measuring AFP before and after the treatment.The effectiveness of RFA. For lesions larger than 3 cm could be increased by several applications or adjuvant therapies should be considered to increase the diameter of coagulation hyperthermic cellular sensitization by chemotherapy [20], vascular clamping [21], or cellular ischemia (chemoembolization) [22] and alteration of electric and thermal conductivity (instillation of saline injection) [23] . Recent progress in bipolar electrodes could provide better control of the shape of large coagulations [24]. HCC is the third leading cause of cancer-related death and the fifth - sixth most common cancer [25-26].The tissue itself is directly heated, rather than the probe itself. [27] above ~50°C, protein denaturation results in irreversible tissue damage. [28]Above ~70 °C, coagulation occurs, where collagens are converted to glucose. Above 100 °C, water vapor develops, and tissue charring can occur, this is undesirable, since it raises the impedance and makes the treatment ineffective. Therefore, impedance between the probe and the dispersive electrode is measured during the treatment, and the generator is shut down automatically if the impedance exceeds a certain value (~ 200 to 1000 W, depending on generator type). [29]

6. Summary and Conclusion

Hepatocellular Carcinoma is one of the most common and dangerous diseases that attacks the human liver, it is considered the fifth cause of death worldwide, in Egypt a high incidence of HCC had been reported, there is a strong association between HCV infection & cirrhosis and HCC.RF ablation (RFA) is a simple, effective, and less expensive technique with a low morbidity compared with surgical treatment RFA can produce significant long-term survival rates and excellent local control. For cirrhotic patients with early-stage, unrespectable HCC Yet, variable factors determine its efficacy e.g. the size of the lesion, its morphology, the operator expertise and low incidence of major complications is usually associated.

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