Ex-vivo experimental study with a new cluster-type microwave ablation antenna

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Abstract—**Microwave ablation which has the advantages of minimally invasive and high-efficiency was more and more used into a number of areas such as cancer treatment. when the tumor diameter is less than 3cm the ablation effect is ideal, but for larger tumors it must be a higher ablation time and a higher power which can result in the reduction of the antenna performance, so the uncertainty of curative effect enhanced. Therefore the study uses in ex-vivo bovine liver to explore the performance of a new cluster-type microwave antenna which has three microwave ablation needles. The temperature distribution and 60℃ isotherm which can decide the scope of the effective ablation were explored. The study carries out with net power of 40W, 60W; ablation time was 5min, 10min, 15min, respectively. For the power of 40W, the maximum temperature, area, volume, diameter and longitudinal diameter was 88.812℃, 9.0511cm^2, 7.917 cm^3, 2.902cm, 3.830cm, respectively with the ablation time 5min while 99.184℃, 19.043 cm^2, 50.936 cm^3, 3.794 cm, 5.835 cm, respectively with the ablation time 10min and 106.094℃, 25.627 cm^2, 81.655cm^3, 4.612 cm, 6.719cm, respectively with the ablation time 15min. For the power of 60W, the maximum temperature, area, volume, diameter and longitudinal diameter was 100.047℃, 25.372 cm^2, 80.345 cm^3, 5.343 cm, 6.908 cm, respectively with the ablation time 5min while 108.863℃, 42.216 cm^2, 185.716 cm^3, 6.319 cm, 8.102 cm, respectively with the ablation time 10min and 110.219℃, 49.803 cm^2, 244.965 cm^3, 7.228 cm, 8.720 cm, respectively with the ablation time 15min. The 60℃ isotherm was ellipsoid-like. Under the same power, the 60℃ isotherm increase with ablation time and at the same time, the 60℃ isotherm increase with power, too. This study may make an important support for the development and clinical application of the antenna.**

Keywords—**Microwave ablation, cluster-type microwave antenna, 60℃ isotherm, diameter**

I. Introduction

Liver cancer is one of the most serious diseases hazards that threatening people around the world for many years. Surgery is not only the best way to treat this disease in tradition, but also a preferred method and the golden standard for successful treatment in clinic[1-2]. However, many patients are not candidates for the surgery, especially someone suffered terminal cancer[3]. Thus, choosing some minimally-invasive and efficient technology, including chemical and thermal methods which have radiofrequency ablation (RFA), microwave ablation (MWA), cryoablation and laser ablation, is becoming a tendency of treating terminal cancer.

On the larger tumor treatment, it's showed that the application of microwave ablation is more widely performed than that of radiofrequency although they are also called minimal invasive techniques due to the larger zone of ablation and less operating time[4-6]. Microwave ablation, the heating not depend on a conduction current path which eliminates ground pad and charring concerns, may allow for more uniform tumor kill both within a targeted zone and in perivascular tissue[7]. Therefore, in allusion to the treatment of large volume tumor, it's a wise decision to prefer the microwave ablation limited by available power and treatment time. Currently, microwave ablation is widely applied in many varieties of possible therapeutic tumors[8-10], especially liver tumor[11].

Despite these theoretical advantages, the MWA still has some imperfection by the single antenna, which achieves the ablation effect of less than 3cm at diameter[12]. In order to attain the aim which is that MW could ablate the tumor size of more than 3cm at diameter, many researchers have studied new type antennas, such as coaxial, triaxial, single-slot[13] and multi-slot[14], and chocked antennas[15]. Nevertheless, the characteristic and ablation effect of the new type antenna are poorly mastered by doctors. So applied the new type antenna in clinic is based on the stay in complete control of the antenna characteristic and ablation effect, which is derived from the ablation effects in ex-vivo and in vivo experiment. Therefore, we studied the ablation effect and zone by the new cluster-type microwave antenna which has three microwave ablation needles in the bovine liver, for the sake of exploring the performance of this new antenna.

II. Materials

The convergence water-cooling antenna of microwave ablation including three needles, designed by Qinghai microwave electronics research in Nanjing, whose microwave instrument generates 2450±50 MHz microwave and adjustable powers ranged from 0W to 100W, is long for 16.5cm, and has three interstitial with the distance 1cm from the conical tip point. In the front of antenna, adopting the 1.5cm unique anti-sticking coating is to avoid the conglutination between the antenna and tissue and improve the conductivity of antenna. Moreover, designing water-cooling is preventing the over temperature of antenna and carbonization. The data acquisition instrument, 34970A, is

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multichannel by Agilent. Due to the large ablation by new cluster-type microwave antenna, choosing the bovine liver as experimental subject is better than choosing the pork liver. Thus, at the high power by microwave ablation, the bovine liver, which is about 80cm^2 as area and 6.5cm as thickness, couldn't ablate thoroughly.

III. Methods

At first, the ex-vivo liver is put into water bath to achieve 37 ℃ which could attain objective of study to get the accurate experimental data. After the ex-vivo liver 37℃, the second is putting the new cluster-type antenna to insert the ex-vivo liver and make sure the tip of antenna to be at original point on the arrangement of temperature needle, as seen at Fig.1. And then it's to make the temperature needle to insert the ex-vivo liver completely and keep in the same horizontal plane with the antenna. Based on above work, the next procedure is starting the cooling installation for water which prevents the antenna overheating from hurting the health tissue including skin, and setting the flow rate as 40r/min at the peristaltic pump. In addition, the powers and heating times, containing 40W and 60W, 5min, 10min and 15min respectively, are applied for ablating. In the ablation process, the temperatures are real-time acquired by data acquisition instrument scanning all channels and recording every three seconds. After scanning, overall data is saved in the computer to analysis in a semi-automatic method by Matlab to reduce the effect of artificial results.

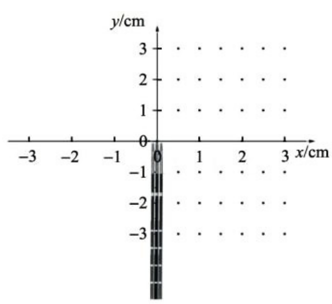


Fig.1 Temperature measuring point arrangement

IV. .Results

According to the experiment of ablation, we got the temperature, the ablation area and the ablation shape from the experimental data. With the increasing powers at the same heating time, the ablation area is enlarging gradually. Similarly, the ablation area is increasing constantly as heating time goes by.

After the ablations, a lot of data by the temperature needles contributed to make the 60℃ isotherm and calculate the area and volume by means of the auto-programming, which was wrote in Matlab. On the basis of the 60℃ isotherm, the ablation situation including the maximum temperature, area, volume, diameter and longitudinal diameter could measure and calculate. From Fig.2, when the heating time was increasing at the same net output power, the ablation area had also increased. Moreover, the ablation area had extended with the net out power increasing.

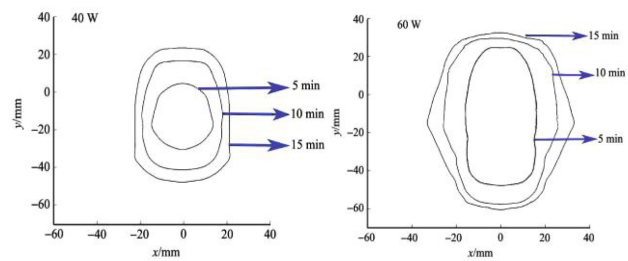
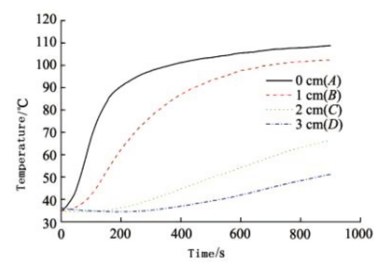
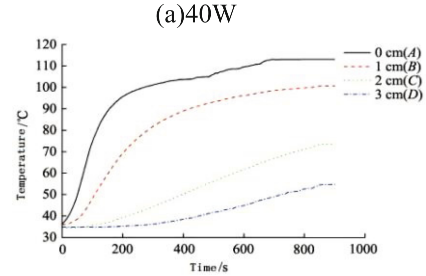


Fig.2 60℃ isotherm by the different heating time

In accordance with temperature data and quantitative data by calculation which described the ablation situation including the maximum temperature, area, volume, diameter and longitudinal diameter, as seen as Table1, the data was increasing as time went on. What's more, at the same heating time, with the net power increasing, the diameter and longitudinal diameter is also increasing gradually (Table 2).



(a)40W



(b)60W

Fig. 3 Temperature curves at 0, 1, 2, 3 cm

Table 1 The experimental data of available power and treatment time

pwer/W	tme/min	maximum temperature/℃	area/cm^2	volume/cm^3	diameter/cm	longitudinal diameter/cm	the rate
40	5	90.812	9.051	17.917	2.902	3.830	0.774
	10	99.184	19.043	50.936	3.794	5.835	0.653
	15	106.094	25.627	81.655	4.612	6.719	0.687
60	5	100.047	25.372	80.345	5.343	6.908	0.778
	10	108.863	42.216	185.716	6.319	8.102	0.776
	15	110.219	49.803	244.965	7.228	8.720	0.838

Table2 The diameter and longitudinal diameter of available power and treatment time

	5min		10min		15min	
power/W	longitudinal diameter/cm	diameter/cm	longitudinal diameter/cm	diameter/cm	longitudinal diameter/cm	diameter/cm
40	3.830	2.902	5.835	3.794	6.719	4.612
60	6.908	5.343	8.102	6.319	8.720	7.228

Owing to the highest temperature in the interstitial antenna and the lateral temperature along the interstitial, which could illustrate the characteristics of the ablation results by the new cluster-type microwave antenna, we selected four points to explain the characteristics, shown as Fig. 3. Meanwhile, the four points were distant between interstitial and points as 0cm that is A(0,-1), 1cm that is B(1,-1), 2cm that is C(2,-1), 3cm that is D(3,-1) respectively.

V. .DISCUSSION

For the power of 40W, with the increasing heating time, the ablation area is larger and larger and the maximum temperature is higher and higher. In detail, the ablation areas is 9.0511cm^2, 19.043 $cm^2$and 25.627 cm^2 respectively at the heating time 5min, 10min and 15min. Besides, the maximum temperature is 88.812℃, 99.184℃ and 106.094℃ respectively at the heating time 5min, 10min and 15min. Meanwhile, the longitudinal diameter including 3.830cm, 5.835 cm and 6.719cm respectively and diameter including 2.902cm, 3.794 cm and 4.612 cm respectively, have also increased. What's more, from Fig.2(a) the value of incremental change at longitudinal diameter is larger than that at diameter, and the incremental change of diameter and longitudinal diameter is reducing as the increasing heating time, which leads the incremental change of the ablation area to reduce. Although the incremental change of ablation area is reducing, the tendency of ablation area is rising and the maximum diameter of the ablation zone passes through the interstitial and is at the perpendicular location of interstitial.

When the net power is set as 60W, as the heating time increasing, the ablation area and maximum are gradually increasing. In detail, the ablation areas are 25.372 cm^2, 42.216 cm^2 and 49.803 cm^2 respectively at the heating time 5min, 10min and 15min. Besides, the maximum temperature is 100.047℃, 108.863℃and 110.219℃ respectively at the heating time 5min, 10min and 15min. However, compared with the net power 40W, the value of incremental change at diameter including 5.343 cm, 6.319 cm and 7.228 cm is larger than that including 6.908 cm, 8.102 cm and 8.720 cm at longitudinal diameter. And it's similar that the incremental rate is also reducing with the increasing heating time compared with 40W from Fig.2(b). Although the incremental change of ablation area is reducing, the tendency of ablation area is rising and the maximum diameter of the ablation zone passes through at the perpendicular location of interstitial.

From the 60℃ isotherm, the maximum diameter is related to the interstitial. Thus, the power generating by interstitial plays an important role in the microwave ablation, and on the basis of that, it could illustrate the characteristic of this new antenna by Fig.3. At first, owning to the effect of rewarming, the temperature is the same one, 37℃, no matter what the heating time and the net power are. With the heating time increasing, the temperature of the point A, located in the interstitial, is rising quickly until 200s, and then the change of temperature is small, which is called platform. As for why this happens, the obstruction of emitted energy by interstitial of the new antenna derives from the water runoff and carbonization of liver which may impede or even block the heat transfer into the tissue.

However, after heating time 600s, the tendency of temperature in point B, at the distance of approximately 1cm away from interstitial, is slowing down but still rising. It's considered that causing this phenomenon is the effect of heat conduction. To the another two points, point C and D, the temperatures are rising slowing in the beginning, which are not affected at the water runoff and carbonization of liver.

VI. Conclusion

According to the experimental data, it indicates that with the heating time and the net power increasing, the ablation area, diameter and longitudinal diameter are also increasing.

At 15min as the heating time, the maximum ablation area, diameter and longitudinal diameter are about 25.627±2.400cm^2, 4.612±0.300cm, 6.719±0.400cm respectively by 40W as the net power. Moreover, at 60W, the maximum ablation area, diameter and longitudinal diameter are about 49.803±2.900cm^2, 7.228±0.100cm, 8.720±0.400cm respectively. Therefore, it has favorable effect in the large tumor by the new cluster-type microwave antenna.

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Conflict of Interest

We declare that we have no conflict of interest.

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