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Author(s)	Bottiglieri, Anna; Elahi, Adnan; Shahzad, Atif; Donlon, Padraig T.; Dennedy, Michael C.; O'Halloran, Martin
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Experimental evaluation of the effective ablation zone on *ex-vivo* bovine liver samples

Anna Bottiglieri, Adnan Elahi, Atif Shahzad and Martin O'Halloran
Translational Medical Device Lab
National University of Ireland, Galway

Padraig T Donlon and Michael C Dennedy
Discp. of Pharmacology and Therapeutics
National University of Ireland, Galway

***Abstract*—Microwave thermal ablation is under investigation for minimally invasive treatments. In the cases of small targets, such as adrenal glands, microwave thermal ablation is a valuable alternative to the traditional and more invasive treatments (e.g. surgical procedures, pharmaceutical therapies). In this work, ablation treatments are carried out on ex-vivo liver samples using a custom developed microwave ablation applicator for ablation of small targets. Ablation zones achieved with different treatment settings are analysed. The power and time settings suitable to achieve a small and well controlled ablation zone, are evaluated. Moreover, the temperature increase in different regions of the area under treatment is assessed.**

Keywords−antenna; microwave thermal ablation; small targets.

I. INTRODUCTION

Thermal ablation therapies are used in medicine to destroy pathological cells, through a localized temperature increase. The ablation effect involves the cell death by necrosis which happens at the temperature over a range of 55-60˚C [1]. Radiofrequency ablation (RFA) and microwave ablation (MWA) are the most common technologies used for thermal treatments [2]. Compared to RFA, MWA provides better performance in terms of geometry of the ablation zone. MWA can create small and precise ablation zones, as higher frequencies (2.45 GHz) than RFA are used [2] [3]. In addition, MWA is a less invasive technique than RFA, as applicators with smaller size (around 1 mm) can be employed. Providing well controlled ablation zone, MWA addresses some of the critical issues of the RFA [2] [3]. Therefore, MWA is emerging as minimally invasive technique to treat lesions in adrenal glands, where a precise ablation zone is required to spare healthy tissues [4]. The shape and the dimension of the ablation zone are strictly related to the applicator design, applied power and the treatment duration [5]. This study analyses the relationship of power and duration with the ablation zones obtained by conducting MWA experiments on *ex-vivo* bovine liver, using a water-cooled monopole antenna at 2.45 GHz [6].

II. METHODOLOGY

Bovine liver was obtained from a local abattoir after one day post-mortem and refrigerated. In laboratory, the sample was dissected in twelve slices, each one prepared into appropriate sizes (approximately 10 cm × 10 cm). The ablation applicator used in this work was developed using an omnidirectional monopole antenna. The antenna was designed using a coaxial monopole by exposing 6 mm of the inner conductor of the feed cable. *Figure 1* shows the device used during this experimental work. The cable was immersed in the water of the cooling system. The applicator was connected to the microwave generator (Sairem 2.45 GHz, Neyron, France) to power the monopole antenna. The antenna was placed on the surface of each liver slice. Moreover, three fibre-optic probes were used, in order to monitor the temperature changes in different zones of tissue, during the ablation treatment. The probes were placed at three different distances from the antenna: 5 mm, 10 mm, 15 mm. Power and time settings of the microwave generator were selected as follows: 50W for 30s, 60s, 90s, 120s; 75W for 30s, 60s, 90s; 100W for 30s, 60s, 90s. The setting time of 120s is eliminated in the experiments with power higher than 50W, as charring started happening in the tissue due to excessive heating. After each experiment, the treated region is measured by a ruler along the longitudinal axis and radial axis, in order to evaluate the growth and shape of the ablation zone. Moreover, by mean fibre-optic probes, the temperature reached in the ablation zone is assessed.

III. RESULTS AND DISCUSSION

In *Table 1,* the results related to the size of the ablation zone obtained with different power and time settings are indicated. Moreover, three different ranges of temperature (T) are shown: T<55°C, 55°C<T<70°C and T>70°C in the table. Different effects are related to each temperature range. Within the range of 55°C<T<70°C (effectively a direct kill zone), an immediate cell death (necrosis) was observed in the underlying tissue. No effect occurs in the case of T<55°C, whereas carbonisation of the tissue appears in the case of T>70°C [1]. The results show that the temperature in the ablation zone is confined to values below 55°C in the case of low duration (30 s), even with higher supplied power, which indicates that the treatment duration under 30s may not produce effective ablation in the target. The size of the ablation zone increases with the duration (60 s). However, in the cases of low power (50 W and 75 W),

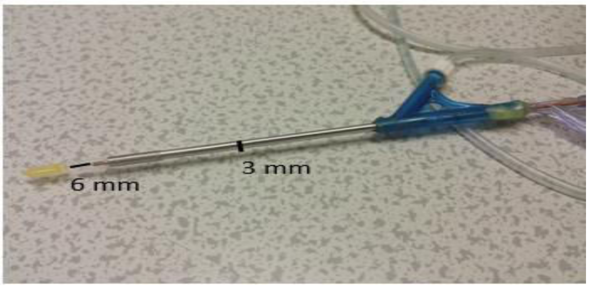

Figure 1: Applicator used for microwave thermal ablation treatments

the temperature remains below 55°C. High power (100 W) for longer duration (60 s or 90 s) is not suitable for small targets, as the surrounding healthy tissue could be damaged due to increased size of the ablation zone. The rapid increase of the temperature produces large kill zones, within the ablation area. *Table I* shows that in the cases 60 s and 90 s and 100W settings, ablation zones of 18 mm and 25 mm are generated respectively, within, which 12 mm and 20 mm are direct kill zones. The results of this analysis suggest that good trade-off is obtained with treatments of low power (50 W or 75 W) for long duration (90 s). In the case of long duration (120 s) and low power level (50 W), the tissue is ablated due to high temperature build-up (T>70°C) over time. The build-up of the temperature is strictly related to the distance from the monopole antenna and treatment duration. *Figure 2* shows the increase of the temperature as a function of the time in the case of 50W power level. The build-up of the temperature is evaluated at three different distances from the antenna, related to the positions of the temperature probes (5, 10, 15 mm). At the distance of 15 mm from the monopole, the peak temperature is below 40°C even after a time of 120 s. The temperature increases linearly in the tissue close to the antenna (within 5 mm radius), but the risk of tissue charring is significant with time duration over 90 s in this case. The temperature remains below 55°C at 10 mm from the antenna, up to a duration of 90 s. After 90 s, again the temperature increases rapidly that may result in an uncontrolled growth of the ablation area. In this case, some healthy tissues may be affected and damaged. Therefore, 90 s duration seems suitable for effective ablation.

IV. CONCLUSIONS

This study was undertaken in order to evaluate power and time settings suitable to obtain a well-controlled and spherical ablation zone. The dimension of the ablation area represents a critical issue, in the cases of small targets (around 10 mm), like adrenal glands. The results of this study demonstrate that the use of low power (e.g. 75 W) for long duration (90 s) can produce well-controlled ablation zone. Furthermore, the results suggest that treatments conducted with high power levels (e.g. above 75 W) result in quick heating of tissue which is not suitable for small targets, and treatment below 30s may not be effective.

TABLE 1: SIZE AND TEMPERATURE OF THE ABLATION ZONE, OBTAINED FOR DIFFERENT POWER AND TIME SETTINGS.

Power [W]	**Time [s]**	**Ablation Area Size [mm]**		
		Size where T<55°C	***Size where 55°C<T<70°C***	***Size where T>70°C***
50 W	30 s	5 mm	-	-
	60 s	15 mm	-	-
	90 s	-	18 mm	10 mm
	120 s	-	20 mm	18 mm
75 W	30 s	10 mm	-	-
	60 s	15 mm	-	-
	90 s	-	20 mm	12 mm
	-	-	-	-
100 W	30 s	10 mm	-	-
	60 s	-	18 mm	12 mm
	90 s	-	25 mm	20 mm
	-	-	-	-

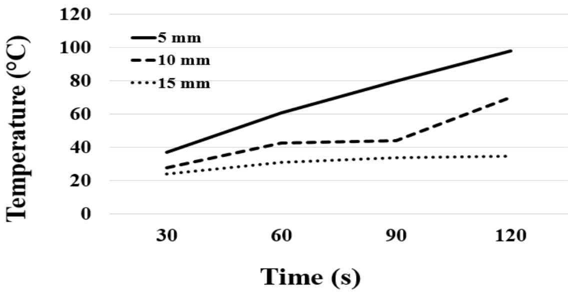

Figure 2: Temperature increase as a function of the time, for three different distances from the antenna (5, 10, 15 mm).

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