Feasibility Study of Microwave Interstitial Applicator Array for Treatment Pancreatic Cancer

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Abstract— The aim of this paper is to check a possibility of usage of interstitial helix applicators for a treatment pancreatic cancer by microwave hyperthermia. This feasibility study is based on the simulations. The simulations were performed in the simulation program of electromagnetic field SEMCAD X for three different frequencies: 434, 915 and 2450 MHz. This paper contains the comparison SAR distribution value (Specific Absorption Rate) simulated on these three frequencies. For simulation procedure was used "High-Resolution Human Models for Simulations: Virtual Population". The final step this feasibility study was to determine the most suitable frequency for the treatment pancreatic cancer on the base of SAR value.

1. INTRODUCTION

The typical characteristics of pancreatic cancer are: a small chance for a complete cure, high mortality and in the majority of cases a tumour is considered inoperable due to the local spread or presence of metastatic disease. The finding the new possible alternatives to the classical approach is highly important. Thus, this work is focused on simulating possible use of interstitial helix applicators for a treatment pancreatic cancer by microwave hyperthermia. More about another possible treatment methods you can find for example in [1] or in [2] where the attention is devoted to treatment by a microwave ablation, which is relatively close to the hyperthermia with the difference that higher temperature is used for the microwave ablation in comparison hypertermia.

2. DESIGN OF APPLICATORS

The simulations for the three different frequencies 434, 915 and 2450 MHz were performed in the simulation program of electromagnetic field SEMCAD X [3]. As the applicators were considered interstitial, the first requirement for helix applicators design was to make them thin as much as possible. For the later possible realization thin enough coaxial cable was chosen. For this reason a size of coaxial cable is corresponding to the size of commercially available coaxial cable with label RG178. Simultaneously the coaxial should be sufficiently "thin" to allow wind the turns of helix antenna on the dielectric without necessity to use a special winding technique.

A diameter of helix was clearly given by the choice of coaxial cable. For the individual frequencies only a length of helix and number of turns were changed. After selecting the suitable coaxial cable, the second step was to do the impedance matching of helix applicator for the aforementioned frequencies. First, the only one helix was placed in a simple homogeneous phantom with dielectric parameters of pancreatic tissue which was taken from the IT'IS FOUNDATION database [4]. The dielectric parameters for all used parts of model are listed in Table 1.

The checked characteristic was the impedance matching respectively SWR (Standing Wave Ratio). For achieving the best SWR the length of helix and number of turns were changed gradually for each single frequencies. It means, every frequency had its helix with specific dimensions after the optimization. And thus these designed applicators were used for the next SAR simulations.

Table 1: Dielectric properties of tissue placed around applicators [4].

	Frequency [MHz]					
	434		915		2450	
	ε_r [-]	σ_e [S/m]	ε_r [-]	σ_e [S/m]	ε_r [-]	σ_e [S/m]
Pancreas	61.33	0.89	59.65	1.04	57.20	1.97
Kidney	65.43	1.12	58.56	1.40	52.74	2.43
Liver	50.57	0.67	46.76	0.86	43.03	1.69
Small intestine	65.26	1.92	59.39	2.17	54.42	3.17
Stomach	67.19	1.01	65.02	1.19	62.16	2.21

3. SIMULATION RESULTS

In the next step were done the simulations of SAR, already by using the matrix of helix for frequency 434, 915 and 2450 MHz. The first SAR simulations were performed in a simple homogeneous phantom with dielectric parameters of the pancreas as well as by detecting the SWR. After obtaining satisfactory results for so called "simple homogeneous model", another simulation of SAR was done for the "anatomical model". For the simulation procedure was used "High-Resolution Human Models for Simulations: Virtual Population" [5] which, together with the dielectric parameters, comes from the pages IT'IS Foundation. In our case it is a virtual family member "Duke" — 34 year old man. For the simulations were considered only bodies in the immediate vicinity of the pancreas, as the proposal for frequencies assumed location 4 applicators around the pancreas.

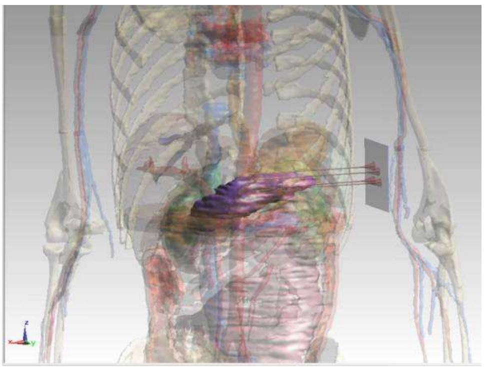

Figure 1: An anatomical model with the highlighted pancreas (violet) and the applicators.

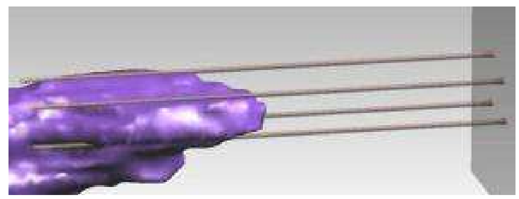

Figure 2: Detail of placing the helix applicators around the pancreas.

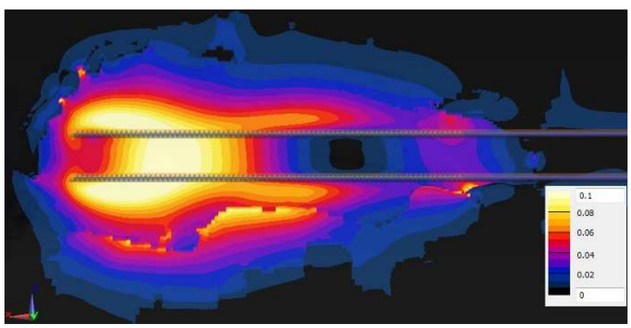

Figure 3: Longitudinal slice Z axis made between the applicators.

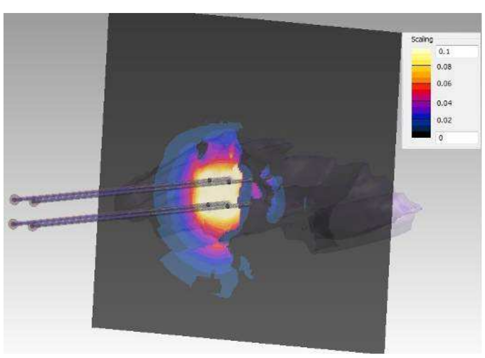

Figure 4: Slice by X axis transversal to the applicators.

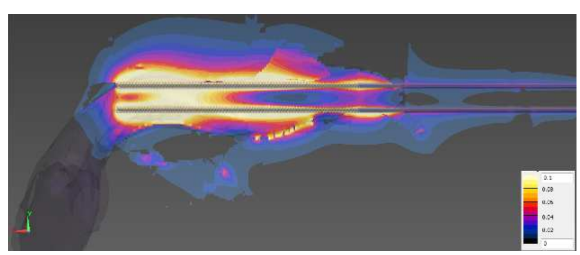

Figure 5: Slice by Y axis is taken longitudinally through the center of two applicators.

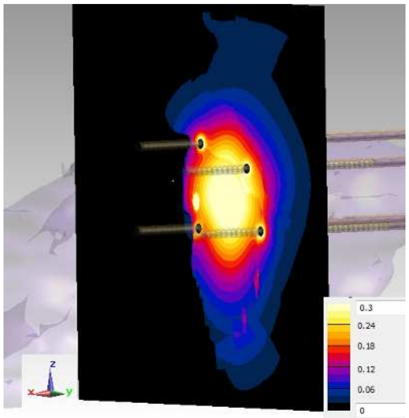

Figure 6: Slice by X axis transversal to the applicators.

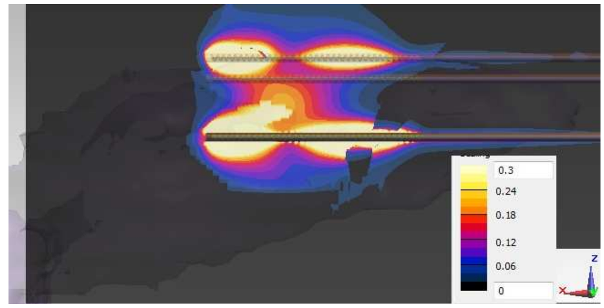

Figure 7: Slice by Y axis is taken longitudinally through the center of two applicators.

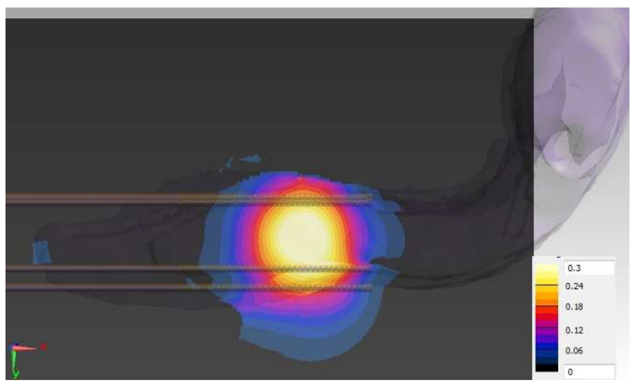

Figure 8: Longitudinal slice by Z between the applicators.

3.1. SAR for 434 MHz

The first simulation shows a distribution of SAR value for frequency 434 MHz. The effort about the good localization of applicators around the pancreas was complicated by the fact that the length of helix applicators was comparable with a length of pancreas. In addition this situation was difficult to handle also due to irregular shape of pancreas. Therefore it was difficult to fulfil another requirement — pierce the pancreas as little as possible. Mostly the applicators are placed only around the pancreas, but in some spots go through the pancreas. In the following figures you can see the distribution of SAR value at a few chosen slices in all three axes.

In the figures it is possible to see that the distribution of SAR value isn't homogeneous in the full volume. The influence of wavelength there is manifested. According the simulations the applicators for frequency 434 MHz are not much suitable.

3.2. SAR for 915 MHz

On the basis of the problems with a too long length of helix, which was designed for frequency 434 MHz, the next simulations were made at frequency 915 MHz. At frequency 915 MHz was enough a half of number turns against at 434 MHz. It was easier to place the applicators around the pancreas.

The figures show that the usage frequency 915 MHz is a much more suitable than 434 MHz. In Figure 8 you can see that the interaction between the applicators is higher. Though the area where the microwave power caused a temperature increase is lower, but it is an expectable result.

3.3. SAR for 2450 MHz

For a small treated area would be more suitable use the frequency 2450 MHz. We have to take in account that the penetration depth is lower for 2450 MHz than for 915 MHz or 434 MHz. But in some special cases could be beneficial.

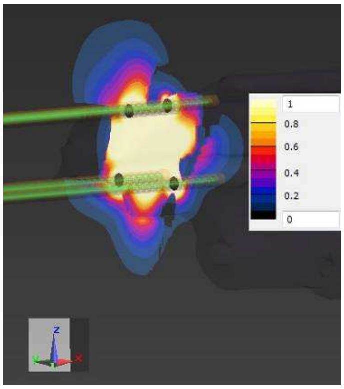

Figure 9: Slice by X axis transversal to the applicators.

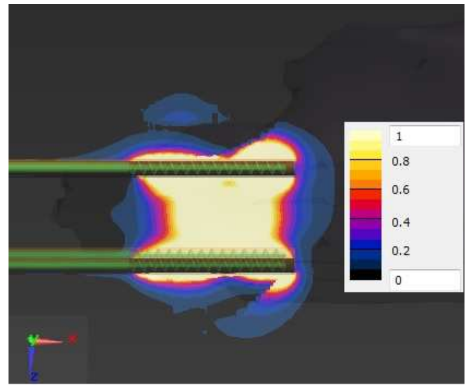

Figure 10: Slice by Y axis is taken longitudinally through the center of two applicators.

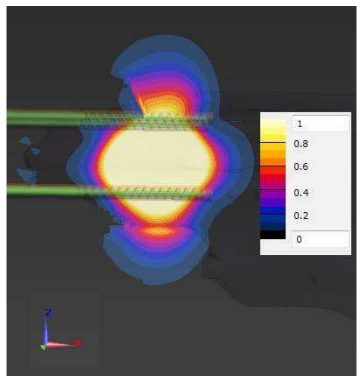

Figure 11: Longitudinal slice by Z between the applicators.

4. CONCLUSION

Using SAR values allows us to calculate very precisely extent of the exposure of biological tissue. By using different frequencies or the lengths of helixes it was possible to influence approximately the size of the area and its volume, which would achieve the highest temperatures. The best SAR value was achieved at frequency 915 MHz if we compare with other two simulated frequencies (434 MHz and 2450 MHz). For frequency 434 MHz the designed helix was calculated too long with too many turns. This fact complicated the suitable location of applicators around the pancreas and also the results of SAR distribution weren't too acceptable. On the other hand usage of frequency 2450 MHz is affected the fact that the higher frequency is used the smaller is the penetration depth. And the treated area is also lower against the other two examples.

The usage of the microwave interstitial helix applicators for treatment pancreatic cancer by hyperthermia rise lots of another questions, like if it was possible in clinical situation and if it is sufficient for completed cure. But maybe it could be used in another type of cancer as a complementary therapy and support of conventionally used treatments.

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REFERENCES

1. Ierardi, A. M., N. Lucchina, M. Petrillo, C. Floridi, F. Piacentino, A. Bacuzzi, P. Fonio, F. Fontana, C. Fugazzola, L. Brunese, and G. Carrafiello, "Systematic review of minimally invasive ablation treatment for locally advanced pancreatic cancer," *La Radiologia Medica*, Vol. 119, No. 7, 483–498, 2014, Online, Doi: 10.1007/s11547-014-0417-9.

2. Keane, M. G., K. Bramis, S. P. Pereira, and G. K. Fusai, "Systematic review of novel ablative methods in locally advanced pancreatic cancer," *World Journal of Gastroenterology*, Vol. 20, No. 9, 2267–2278, 2014, Doi: 10.3748/wjg.v20.i9.2267, Dostupnéz: http://www.wjgnet.com/1007-9327/full/v20/i9/2267.htm.
3. Schmid & Partner Engineering AG, Semcad X, 2010, Available from http://www.semcad.com.
4. Hasgall, P., E. Neufeld, M. Gosselin, A. Klingenböck, and N. Kuster, "ITIS database for thermal and electromagnetic parameters of biological tissues," 2011, Online Available: www.itis.ethz.ch/database.
5. Andreas, C., W. Kainz, E. G. Hahn, K. Honegger, M. Zefferer, E. Neufeld, W. Rascher, R. Janka, W. Bautz, J. Chen, B. Kiefer, P. Schmitt, H.-P. Hollenbach, J. Shen, M. Oberle, D. Szczerba, A. Kam, J. W. Guag, and N. Kuster, *Physics in Medicine and Biology*, Vol. 55, No. 2, N23–N38, Jan. 2010, Available: http://iopscience.iop.org/0031-9155/55/2/N01/.