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ANALYSY HEAT PROPAGATION TIME OF BASE UNTIL TIP OF TROCARTES USING FINITE MODELS ELEMENTS

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ABSTRACT
The purpose of the hepatic RF ablation is to use the heat to destroy cancer cells to avoid the liver metastases. This mini-invasive techniques uses an electrode with multiple lengthening inserted into the tumor region and the radio frequency (RF) is produced by an electronic generator. The heat generated in the tumor causing their necrosis, i.e. the cells are destroyed due to increased temperature. Thus the procedure, when successful, allows controlled heating in a well-defined volume of the tumor in the liver to eliminate completely carcinoma. Therefore, the radiofrequency ablation (RFA) can cure the patient of the cancer. The geometric characteristics: diameter, length of the electrode and a position are described in the following table. Basically, it was constructed two catheters, one of 3.5 mm and other of 4.0 mm of diameter, which contains eight electrodes umbrella format. Moreover, each catheter electrode vary in length and hollow and in the solid structure. Soon the analysis is done with two catheter 3.5mm and 4mm, each with arc length of electrodes 10, 15, 20 and 25 mm, hollow and solid structure. The model shows the system mechanical effect on the fabric with the temperature rise with time around the electrode.

INTRODUCTION
The hepatic ablation for radiofrequency (HRFA) is a therapeutics option largely used for hepatocellular carcinoma (HCC). The process consists in the change of electromagnetic energy in thermic. This transformation is obtained because the electric field vector (E) in a conductive mean is always is perpendicular at a magnetic field vector(B), wherein the electric field vector (E) alternate cause agitation in the current ions in the tissue that through friction produces heat around of electrode causing ablation. The temperature and the exposition time correct shall result in the destruction, coagulation or tissue carbonization affected for cancer. For this is recommended that the electrode will be positioned in 2 cm bigger than diameter of tumor for realization of the ablation [1].
A robust system of Ablation radiofrequency should produce ablation zone predictable to include tumor tssue avoiding the metastasis. However, a limited factor is the size of tumor to be treated, particularly whether the tumor is bigger than 3 cm is preferable to use a surgical technique to clearance of carcinogen tumor, surgical hepatic resection (HR), nevertheless, in tumors smaller than 3 cm, the technique more used is the hepatic ablation (HFA) [2].

This away, the relation between heat transfer and ablation volume is the study object this paper, highlighting the interaction of electrode with the stayed tumor, due the fact that the starting of analysis of information of temperature transmitted for the electrode is possible to modify the extension of tissue area[3].

For this is showed the modeling of finite element in 3D of three kind of Trocarte. The distribution of temperature and the tissue heat estimation is determined according with the electric field parameters, tissue density, model conductivity and ablation area extended using each Trocarte with different formats electrode.

MATERIALS AND METHODS
The ablation electrode model is built in “Computer Aided Design” (CAD) with three dimensions and represented for Finite Models Elements (FEM). The current work adopted the COMSOL software version 5.0 as simulation tool used the FEM.

Definition of geometry
The figure 1 shows the geometry Trocarte in study. The Trocartes for hepatic ablation in general have a little caliber and formats different to reach the target region. In this study were considered the diameters of the Trocarte with 3.5 and 4 mm, with one and several active electrodes.

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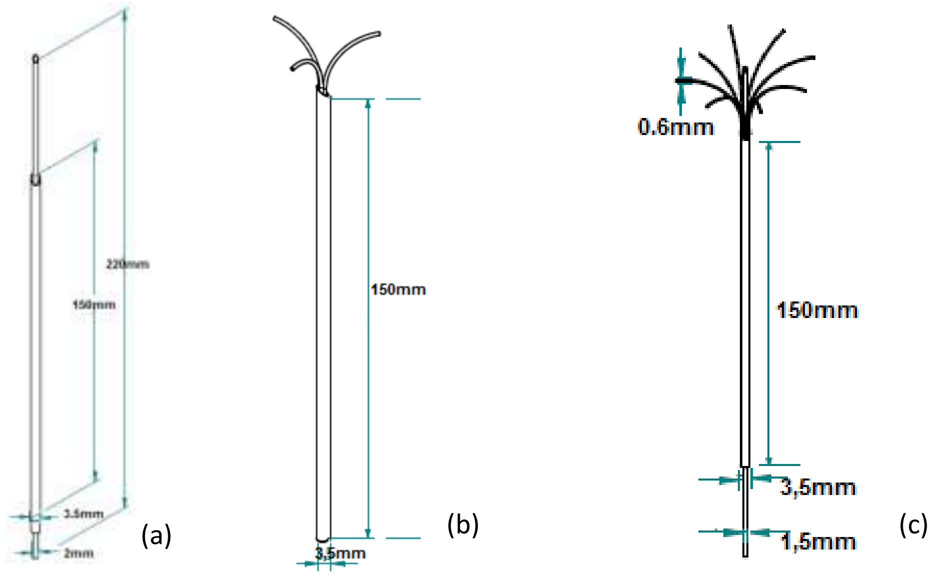

Figure 1. Electrode Geometry for hepatic ablation system.
(a) Pencil Trocarte, (b) Trocarte Three, (c) Umbrella Trocarte

The Trocarte electrode multiple have the aspect of a curvilinear cone of center to the edges, outside the tube has a maximum amplitude of 25 mm and angle of 90° together to electrode center. In the table 1 is describe the caliber dimension for the elements that make up each trocarte.

Table 1. Trocarte dimensions: Body Outside and Inside of each electrode

Kind of Trocarte	**Diameter (mm)**		
	Trocarte of insertion: Body Electrode Outside	Center Electrode Active: Body Electrode Inside	Electrode Active
Pencil	3.5 4.0	2.0	--
Three	3.5 4.0	--	1.5
Umbrela	3.5 4.0	1.5	0.6 0.8

The Trocarte development has the actives electrode and a ground plane connected to patient. Each electrode can contain a thermocouple to temperature read in the medium point or outside of electrode. This way is possible to regulate the power application at patient body.

Material Definition

The basic model of the Trocartes in CAD is compound for following parts according with the desirable characteristics each one:

- Body Trocarte outside: must be material semi-rigid and isolated electrically of the electronics components.
- Body Trocarte inside: must be material semi-rigid and isolated of Trocarte outside; must be his sharp edges in angle minimum of 60°; must be active and have 25 mm of contact area;
- Complementary Electrode: must be material semi-rígid and isolated of body outside; must be active and must have memory form with a arc of 90° of 25 mm of distance of center electrode. The material chosen must be based in the efficiency measure of heat transfer and dissipation due the thermic fluctuation in consequence of electric charges or ions in the material.

Global Journal of Engineering Science and Research Management

Electrode: Nickel-titanium (NITINOL)

Nowadays, the shape memory alloys (SMA), is in especial, Nickel-titanium alloys (NiTi), It's generally used in biomedical applications due the biocompatibility, excellent magnetic resonance and compatibility a computed tomography. Besides, the mechanic behavior of the NiTi is more similar the response of biologic tissue in comparison with the other metallic material generally used for biomedical device, as the stainless steel 316L and Cobalt-Chrome (Co-Cr) alloys [4]. The material propriety used is described in the table.2.

Table 2. Nitinol property

Name	Value	Unit
Thermal conductivity	18	W/(m*K)
Density	6450	kg/m^3
Heat capacity at constant pressure	840	J/(kg*K)
Electrical conductivity	1e8	S/m
Relative permittivity	1	1

Stainless Steel 304

The stainless Steels is frequently used in biomedical application, such as orthopedic implants, due the propriety with high resistance at corrosion and fatigue, just like, high resistance at fracture. Beside biocompatibility, these properties are important in the selection and adaptation of a material for biometric application [5].

Table 3. Property of Stainless Steel

Name	Value	Unit
Electrical conductivity	1e-5	S/m
Thermal conductivity	0.026	W/(m*K)
Density	70	kg/m^3
Heat capacity at constant pressure	1045	J/(kg*K)
Relative permittivity	1	1

Thermal conduction for Biological Systems

The electrode adopted was set monopolar considering the no linearity of electric conductivity in term of temperature, such the temperature is the bigger than 105°C, unfeasible the electric conductivity. The heat conduction in biologic tissue is model for the Pennes' bio-heat transfer equation [6]:

$$\rho c \frac{\delta T}{\delta t} = \nabla k \nabla T - c_b w_b (T_a - T) + q_m \quad (1)$$

- ρ, c *and* k, density (kg/m³), the specific heat (J/(kg.K));
- w_b mass flow rate of blood per unit volume of tissue (Kg/(s.m³));
- c_b blood specific heat;
- q_m metabolic heat generation per unit volume (W/m³);
- T_a represents the temperature of arterial blood (K;
- T temperature rise above the ambiente level;
- $\frac{\delta T}{\delta t}$ is the rate temperature rise.

Table 4. Parameters of tissue and the blood for Simulation of thermic conduction.

Name	Expression	Description
$\boldsymbol{\rho_b}$	1000[kg/m^3]	Density sangue
$\boldsymbol{C_b}$	41802[J/(kg*K)]	Heat capacity, blood
$\boldsymbol{w_b}$	6.4e-3[1/s]	Blood perfusion rate
$\boldsymbol{T_b}$	37[°C]	Arterial blood temperature
$\boldsymbol{T}$	37[°C]	Initial and boundary temperature
P	[kg/m^3]	Density, liver
C	[J/(kg*K)]	Heat capacity, liver
K	[W/(m·K]	thermal conductivity

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Transmission for Radio frequency

The relation of heat transmission for radio frequency is providing for the especial heat source q_m defined for the SAR distribution generally used for biologic tissues. The equation 2 shows the heat generated for the electric field vector (E) in the tissue:

$$SAR = \frac{\sigma}{\rho}E^2 \quad [\frac{W}{kg}] \qquad (2)$$

- σ tissue conductivity [S/m];
- ρ tissue density [Kg/m³];
- E electric field vector[V/m].

RESULTS AND DISCUSSION

The simulations were performed in trocartes model with 1, 2 and 3 electrodes, with variation of length, solid structure and Nitinol material of the electrode. The figures bellow show the simulation outcome for three kinds of trocartes analyzed according with his response and profiles temperature.

Figure 2. Pencil trocarte

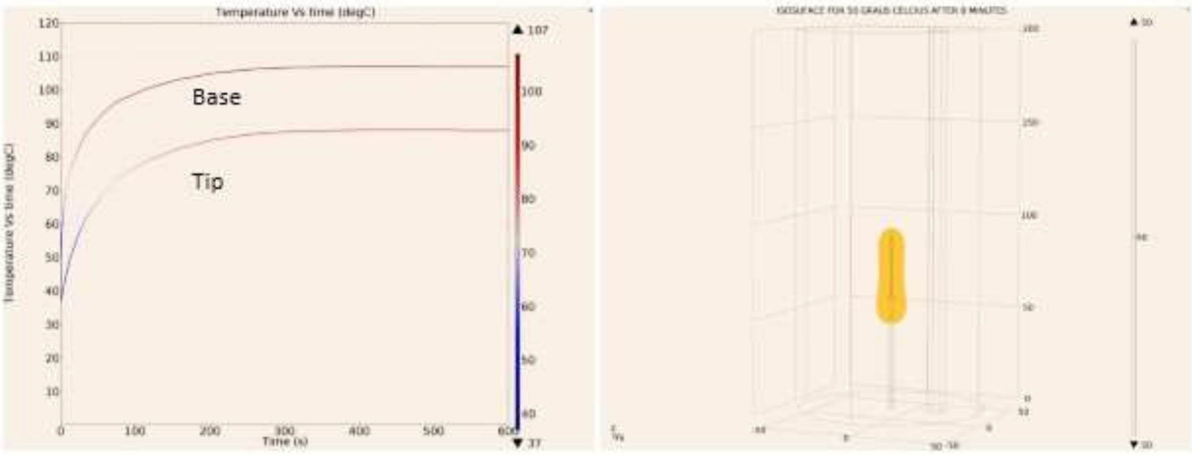

Figure 3. Trocarte Three

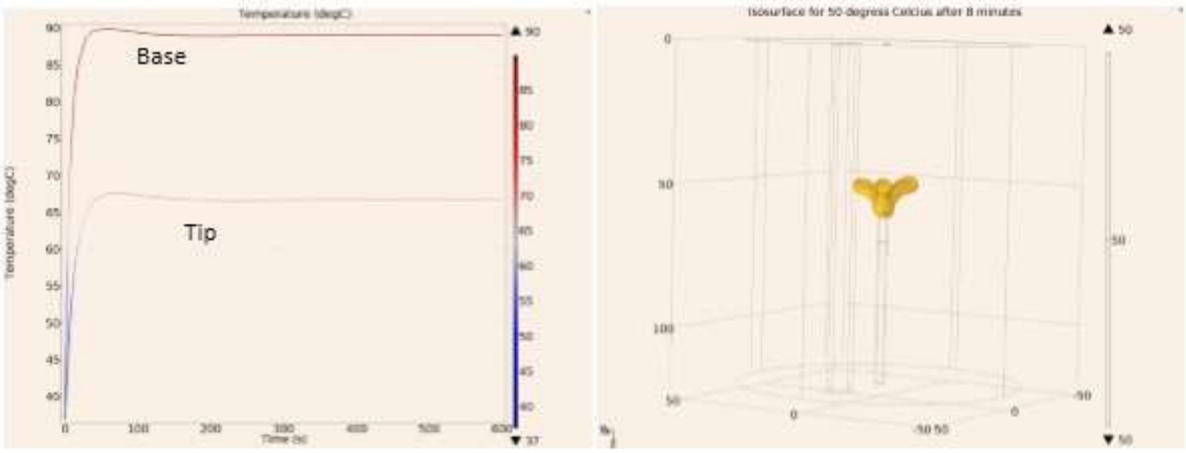

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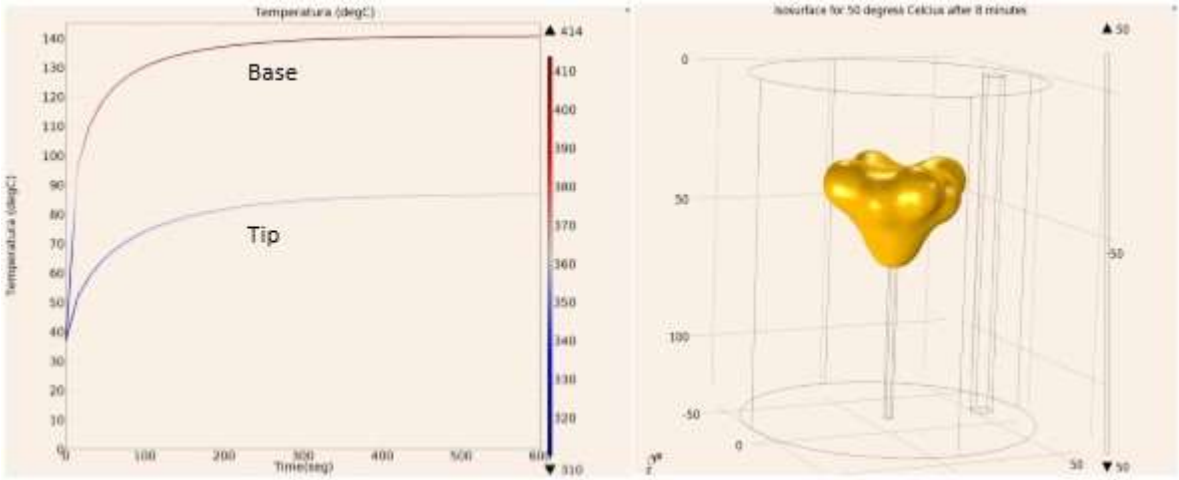
Figure 4. Umbrella Trocarte



The figures 2, 3 and 4, is observed the simultaneous response of temperature during the 600 seconds of analysis that matches the two points of the evaluation: the electrode base and tip. These analysis shows how long does it take to the heat propagation of the base until tip electrode. In each model analyzed is noticed the behavior reference the propagation change, wherein in the trocarte three the propagation occurs faster than the analyzed models. it can be noted all the analyzed models have the time propagation of base to tip about 10 seconds whether considered a fixe temperature of 50°C with reference, this factor is important in the question of control of temperature to realize the hepatic ablation.

It is considering that the molecules friction are close to the electrode tip, so that actually it will occur the necrosis, The profile analyzed reference at time propagation of heat it becomes enough relevant in the definition of temperature adequate in the base that consequently it is will reflect in the tip, in the words, in the general context, is need to fix the thermocouple in a adequate position to read the correctly temperature the practical point of view.

The temperature profile indicates different standards achieved to each one of models, The studies reveal that the choice of trocarte models, it has influence in the ablation time according size of tumor, according the focus of study, for each volume of tumor established is necessary a time of exposition adequate keeping the temperatures conditions for the necrosis of the cancer cells. All the models show a rate of temperature between 50 and 100°C, it is according with the indicate for the technique. However, should check the parameters to give a temperature profile more uniform of models, in the words, the achieved the temperature more high whether in more times.

The homeostasis cells can be keeping until about 40°C. As the temperature increases, the cells stay more and more susceptible at heat effect: At 46°C are needing 60 minutes to cause injury to the cell irreversible, but at 50-52°C is only necessary 4 at 6 minutes. The temperatures is bigger than 100°C, because exceed the point water bulling, it is results in vaporization and carbonation of tissue, it reducing the volume of coagulation due the isolate effect of gas produced, this fact reduces the deposition of energy and the thermal conductivity tissue.

CONCLUSION

The energy values more highs are necessary to the ablation is the bigger tissue volume, however, the cells tissues that are hitting more quickly stay as electric isolate that reduce the contact superficies electrode and increase the current density. Therefore, the control of energy deposition in the system will be measured to decrease the superheat and to increase the current density and standardize the temperature profile.

The injury quantity of tumor tissue starting of a standard of temperature distribution could define the energy deposited for the place tissue and each to control the margin of the healthy tissue, what is a limiting in the injury structures close to tumor. The burn should occur so to avoid the liver metastasis and guarantee that all the cancer cells would be fully destroyers.

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The Elements finites methods (FEM) show the advantage to simulate parameters and thermal conduction behavior for the biologic systems before of prototype construction, it is allowing the correction of dimensions and early fails.

All this studies realized are base to the development of a hepatic ablation equipment it's has being built for a science team of the University of Brasilia. The proposed is to validate those outcomes with an equipment robust development for treatment of cancer patient.

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