A treatment planning of radiofrequency ablation for spinal tumor

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Abstract

Background: To establish a treatment planning to predict therapeutic parameters accurately and avoid other healthy tissue damage by radiofrequency ablation (RFA) in spinal tumor.

Materials and Methods: According different therapeutic parameters (voltages 10-30V and heating-up time 120-1200s) and structures of electrode, the ablation results were achieved by finite element method to build a database. For the purpose of predicting therapeutic parameters in the treatment planning through the database, we chose three modes to compare the best one, including back propagation (BP) neural network, general regression neural network (GRNN) and support vector machine (SVM).

Results: Small tumor (maximum diameter<30.0mm) could be ablated by single needle electrode, and large tumor (maximum diameter≥30.0mm) should be applied by multi needle electrode. Besides, acquired 383 sets of data were regarded as database by the simulation. Compared with the other two models, SVM model is the best one to be applied in the treatment planning, in which error rates(0 and 0.33%) were the smallest and correlation coefficients(1.000 and 0.999) were the closest to 1. To verify whether the ablation results are correct, we have compared them to the clinical treatment results and previous studies.

Conclusions: This treatment planning by SVM is accurate to predict voltage and heating-up time, and it has higher correlation coefficient and few errors.

Keywords: Spinal tumor; radiofrequency ablation (RFA); SVM (support vector machine); treatment planning

Abbreviations: RFA, radiofrequency ablation; BP, back propagation; GRNN, general regression neural network; SVM, support vector machine; MWA, microwave ablation

Introduction

Spinal tumor is an uncommon disease in the primary tumors, while, it has been a kind of serious metastatic spinal tumors in clinic. It has been divided into three types, including primary benign, primary malignant and metastasis spinal tumors [1]. As reported in USA, there were 11712 patients suffered from spinal tumors including 2576 cases of malignant primary spinal tumors and 9136 cases of primary benign spinal tumors in 2004-2007 [2]. So applying a highly efficient method to treat spinal tumors is desiderated in clinic. Despite surgical resection is still the main effective method to treat various tumors [3], thermal ablation is under development for spinal tumors currently [4]-[5], on the basis of its clinical utility and safety for treating liver, lung and bone tumors [6]-[8]. Raising tissue temperature in the target volume to induce coagulative necrosis is the goal of thermal ablation, which contains RFA, MWA and so on. The energy of radiofrequency is less than microwave energy, which could avoid damage of nervous tissue availably by small tissue of coagulation necrosis [9]. So the method of RFA is widely used in treating spinal tumors. In addition, the complexity of the spine anatomical structures in the surgical treatment of spinal tumors is difficult, in recent years, some scholars explore imaging guided RFA technology was applied to part of the treatment of spinal tumor, has obtained the good effect [10]-[12], for the minimally invasive treatment of spinal tumor provides a new way. In some studies [13]-[14], osteoid osteoma whose diameters are generally between 2 and 14mm has been treated by RFA, and it has verify that applying RFA is both feasible and safe for the treatment of painful primary benign tumors. According to the previous studies [4][9][15][16], using RFA to treat metastasis spinal tumors has obtained satisfying effect in clinical. Hillen et al [15] applied CT to achieve the aim of monitor and navigation to guide the RF electrode and had better effect (the maximum ablation area about 30mm long and width 20mm) in clinical based on 26 patients. And it's also illustrated the feasibility and safety by RFA in spinal tumor. Furthermore, Wallace et al [16] researched 72 patients of spinal metastases by RFA from 2012 to 2014, and explained the availability of this method at the average 8min32s ±4min49s heating-up time. However, due to the complex environment of spinal tumors which could be located close to the spinal cord or neural, studies have demonstrated that the aim is to both get large target volumes and prevent the risk of neural or spinal cord damage [9][17]. There are still many challenges in clinical hasn't been solved yet, such as the other tissues get thermal injured caused by different heterogeneity, how to real-time monitoring melting process, avoid the interference of the vascular structures and neural structure as well as electrode of the RFA probe insertion ways. So some researchers [8][13][14][17][18][19] have developed the planning system to assist surgeon or use ultrasound assistance in the treatment of spinal and other tumors, based on the imaging technology, such as CT, MR or X ray. Among that, studying possibility of subject specific precise offline microwave thermal ablation treatment planning is based on the CT and MR [18]. However, nerve injuries have been reported more frequently in series of heat-based ablation of spinal tumors in close proximity to the spinal cord or sacral nerve roots [20]-[25]. Many neural structures are not well depicted with the imaging modalities most commonly used to guide thermal ablation, namely ultrasound and CT. Pre-procedural imaging with MRI is frequently valuable to evaluate the proximity of neural structures to the target tumor. Likewise, CT angiography may be helpful to depict vulnerable vascular structures supplying the central neuro axis, namely the radicular and vertebral arteries. Alternatively, tumor ablation may be performed under MRI guidance in some medical centers to improve visualization of these neural structures intraprocedurally. Immediate pre-ablation myelography may facilitate recognition of the proximity of the spinal cord or nerve roots when performing ablation in the spine and sacrum [26]. And according to the open source image-guide surgery toolkit, presenting three image-guided systems for needle-based interventional radiology procedures is significant [19]. Therefore, establishing a feasible treatment planning is essential to assist physicians, which is focused on the accuracy ablation to avoid spinal cord damage.

Empirically, it's believed that data of vitro experiment and simulation is the basis of clinical treatments [27]. In the previous studies we have based on a true database set up personalized microwave thermal therapy of spinal tumor surgery planning ,which includes according to the patient's medical slice images 3d reconstruction of the real geometry of tumor and its surrounding tissues, imposed by the in vitro experiment measured SAR boundary conditions, using the finite element method for temperature field simulation [28].Nevertheless, containing all kinds of spinal tumors ablation results completely in the database is impossible. According to the shape and size of spinal tumor including maximum axial length, maximum transverse width and maximum vertical depth, it's essential to calculate and predict precisely the therapeutic parameters containing voltage and heating-up time. In addition, the great target volume is sensitive to the heating-up time and voltage in the radiofrequency ablation.

Owing to nonlinearity between therapeutic parameters (voltage and heating-up time) and ablation results, artificial neural network is employed to achieve the aim of treatment planning in the view of limited samples [29]. Currently, SVM [30], BP neural network and GRNN [31]-[32] are benefit to regression analysis prediction model for nonlinear multi-input multi-output.

This prospective study was to build a database about the relationship between accurate ablation results and therapeutic parameters. And the model of SVM was applied in the treatment planning to assist surgeons to estimate the therapeutic parameters including setting voltage and heating-up time. A treatment planning in spinal tumors is an essential tool to determine the therapeutic parameters rapidly and accurately, and it also can assist surgeons in the radiofrequency ablation of spinal tumors.

Methods

Simulation of spinal tumors in RFA

Because of multi-physics field solving comprehensive model exactly, this study applied ANSYS workbench as simulation soft to establish electromagnetic field and thermal field coupling. Among that, the frequency of electromagnetic field is at the lower frequency (460KHz), so using the Maxwell formulation to calculate the field is following by equation1-4 [27][33]-[35]. In the simulation, the blood perfusion rate could be ignored for ideal model. So the power generated by the RF was converted into the heat energy to make tumor temperature rise. Meanwhile, Pennes equation [36] was applied in simulation as the heat field in equation5.

$$\nabla \cdot (\sigma \nabla V) = 0 \tag{1}$$

$$E = -\nabla V \tag{2}$$

$$J = \sigma \cdot E \tag{3}$$

$$Q_r = J \cdot E \tag{4}$$

where V is the voltage (V), σ is the electrical conductivity (S/m), J is the current density (A/m^2) and Q_r is the volumetric heat generation rate (W/m^3) about electromagnetic heating.

$$\rho c \frac{\partial T}{\partial \tau} = k \nabla^2 T + \omega_b c_b (T_b - T) + Q_m + Q_r \tag{5}$$

where ρ is the tissue density (kg/m^3), c is tissue specific heat capacity(J/(kg·℃)), k is the thermal conductivity of tissue (W/(m·℃)), T is the temperature of tissue(℃), τ is the time (s), c_b is the specific heat capacity of blood (J/(kg·℃)), ω_b is the blood perfusion rate (kg/(m^3·s)), Ta is the blood temperature in the heating zone(℃), Q_m is the heat energy of biological tissue (J/(m^3·s)), Q_r is the energy of the external heat quantity.

Due to different sizes of spinal tumors, we built two kinds of the 3D ideal models to descript the comprehensiveness of ablation results in this study, including single needle electrode and multi needle electrode, which were regarded as common electrodes in clinic. But is questionable, the multi-needles electrode of the RFA probe may not even be opened as some spinal tumors are hard in consistency. In spite of this, the STAR Tumor Ablation System (DFINE, San Jose, CA) has designed can be curved up 90 degrees of bipolar needle electrode used in bone tumors [37], prove its effectiveness and safety , declare that there has further work can be carried out. The structures (Fig.1) of electrode is from previous studies [9][38]-[40].

(a) **(b)**

Figure1. (a) The structure of single needle electrode is divided into two cylinders including electrode tip and insulating shaft, meanwhile the diameter of cylinder is 1.8mm. The length of electrode tip and insulating shaft are 20mm and 60mm respectively.
(b) The structure of multi needles electrode [30] is divided into two cylinders and four needles. Among that, the length of two cylinders including electrode tip and insulating shaft are 10mm and 90mm respectively, meanwhile the diameter of cylinder is 1.8288mm. The distance is about 15mm between the bottom of electrode tip and each needle. Moreover, the diameter of four needles is 0.5334mm.

The boundary of electrode tip and insulating shaft are regarded as Dirichlet boundary and

Neumann boundary respectively [9][41]. Therefore, constant voltage is applied on the active part of the electrode and the ground is acted as other boundary. Material parameters in the numerical simulation are shown in Table 1.

Table 1. Thermal parameters of each material

Materials	k (W/m ·℃)	c (J/kg ·℃)	ρ (kg/m^3)	F(s/m)
Spinal tumor	0.42	4100	1000	0.4
Electrode tip	71	21500	132	4e6
Insulating shaft	0.026	1045	70	1e5

As reported, the time of solving pre-processing and post-processing could account for 95% by finite element simulation, besides, the time of analysis and solution spends less time which occupied 5% approximately [42]. So solving pre-processing is great significant to simulate by finite element method, especially mesh generation to determine whether or not the scientific and rational calculation results. We applied three kinds of grids namely coarse, medium and fine to generate, which could create mesh refinement. Among that, the mesh elements are respectively 16891, 55265 and 57937, as well as the element qualities are 0.93, 0.97 and 0.90 sequentially. According to the standard of meshing quality [43], the second case has high meshing quality by comparison, as enough mesh elements. Besides, in the second case, a majority of element quality is almost more than 0.95 by calculation, which could achieve the aim of great precise and logical ablation results.

Owing to the therapeutic parameters including voltage and heating-up time, we choose effective parameters in clinic. Based on previous studies [9][27][33][44][45], voltage supplied from transducer was allowed from 10V to 30V, moreover, the heating-up time was set from 120s to 1200s at intervals of 60 seconds. Meanwhile, to avoid high temperature (>100℃) to cause carbonization and hurt healthy tissue, keeping the highest time below 100℃ is necessary.

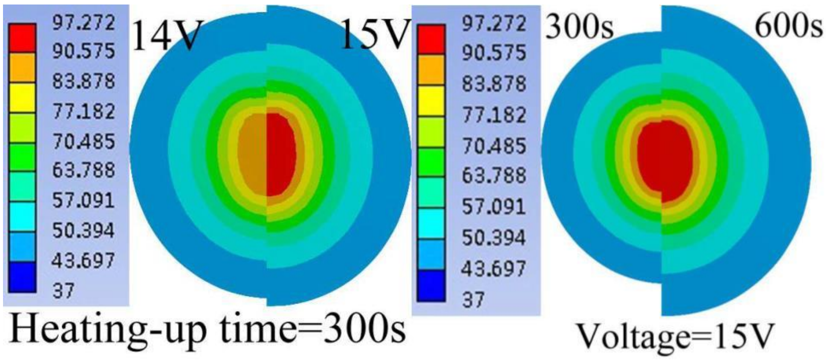
The treatment planning

To predict the therapeutic parameters (voltage and heating-up time) for providing the treatment data of surgical planning, it is essential to apply regressive prediction model to explore the relationship between therapeutic parameters and ablation results, based on several uncorrelated factors to affect ablation results. In the light of current studies about prediction models [29]-[32], three kinds of models have been used popularly, and they fit our simulation results characteristics, including BP neural network, GRNN and SVM. To verify the accuracy of prediction data and evaluate the superiority-inferiority in three models, randomly selecting 20 sets of data from simulation data (383 sets), including therapeutic parameters and ablation results, is regarded as test data. Among that, the voltage and heating-up time were predicted by the different models on the basis of characteristic between therapeutic and ablation results in database except the selected 20sets of data. Besides, the prediction data must be contracted with the actual data, which could prove the scientific nature of the evaluation model.

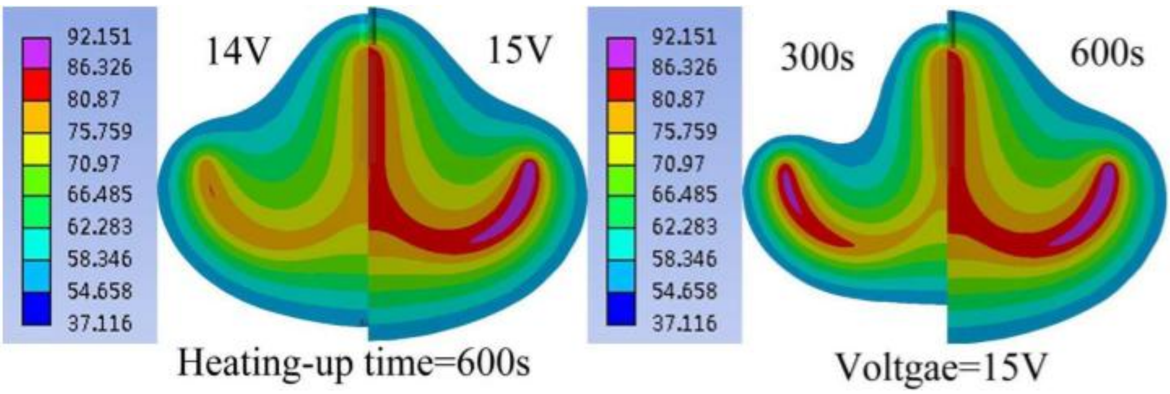
Results

Simulation of spinal tumors in RFA

Fig.2(a) shows the temperature distribution of various therapeutic parameters after simulation by single needle electrode. It was observed that the temperature distribution was symmetric and similar to rotundity. Whereas, the temperature distribution of multi needle electrode presented a mushroom shape in Fig.2(b), and with increasing the voltages or heating-up time, the temperature distribution had a tendency to expand a mushroom shape, particularly the concave changing, which was conformed the clinical research status compared with other studies[38][40].



(a)

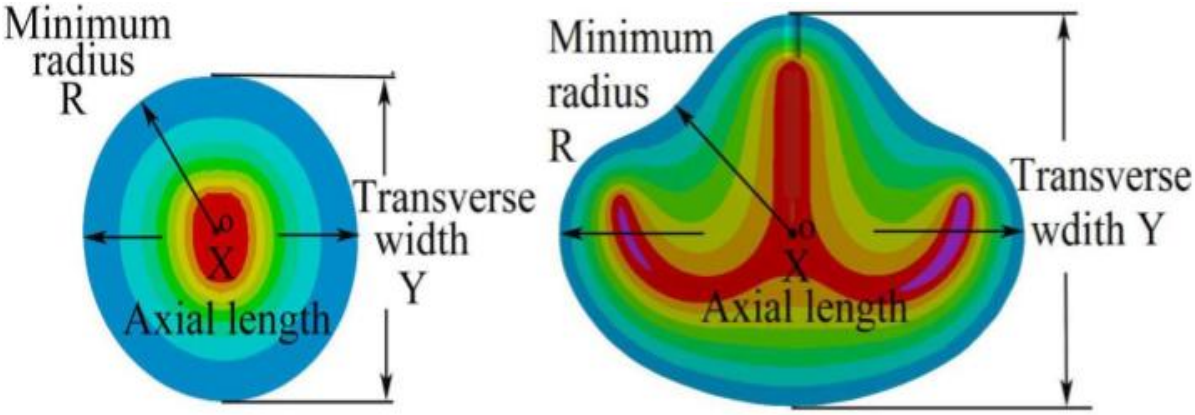


(b)

Figure2. (a) With increasing heating-up time and voltage, the temperature distribution(54℃) by single needle electrode is expanding as spherical shape.
(b) The temperature distribution by multi needles electrode is a mushroom shape at different heating-up times and voltages.

To illustrate the influence of therapeutic parameters (voltage and heating-up time) on ablation results including axial length(X), transverse width(Y) and vertical depth, we have measured the parameters of lesion to indicate the changing ablation results (see in Fig.3) and chosen some simulation results to summarize the variation in Table2 and Table3. The simulation results by single needle electrode were that the volume range of ablation zone was 70-17549mm^3, and the transverse diameter range of ablation zone was 5.4-31.8mm. So the small diameter (<30mm) spinal tumor could be treated by the single needle electrode in clinic. Furthermore, the volume range of simulation results by multi needles electrode was 81-130179mm^3. And the ranges of transverse diameter and minimum radius were 31.4-69.4mm and 3.9-30.1mm. The big diameter

(⩾30mm) spinal tumor could be treated by the multi needles electrode in clinic. Compared with previous studies [13]-[16] about spinal tumors in clinical, our simulation results contain different sizes ranged between 2 and 40mm spinal tumors including primary benign, primary malignant and metastasis spinal tumors.



(a) By single needle electrode **(b) By multi needles electrode**

Figure3. The diagram vertical profile about temperature distribution (54℃) of the parametersmeasured. Among that, it shows axial length(X) and transverse width(Y) at the origin(o). The minimum radius(R) is to illustrate the peculiarity of temperature distribution, especially by multi needles electrode.

Table 2. Ablation results at different therapeutic parameters by single needle electrode

		14V				15V			
	Heating up time	X (mm)	Y (mm)	R (mm)	Volume (mm^3)	X (mm)	Y (mm)	R (mm)	Volume (mm^3)
Single needle electrode	300s	13.39	13.37	6.68	954.56	13.41	13.37	6.69	1175.13
	600s	16.36	15.94	7.97	1576.54	17.33	16.49	8.25	2032.27
expansion rate(%)		22.16	19.22	19.22	65.15	29.23	23.33	23.31	72.94

Table 3. Ablation results at different therapeutic parameters by multi needle electrode

		14V				15V			
	Heating up time	X (mm)	Y (mm)	R (mm)	Volume (mm^3)	X (mm)	Y (mm)	R (mm)	Volume (mm^3)
Multi needle electrode	300s	40.94	28.55	8.38	9089.2	42.34	29.52	9.65	10315.00
	600s	45.94	34.58	10.41	19650.3	48.93	36.88	12.95	23637.10
expansion rate(%)		12.21	21.12	24.22	116.19	15.56	24.93	34.19	129.15

As shown in Table2, with the increase the heating-up time, the expansion rate of axial length was 22.16%, meanwhile the expansion rate of transverse width was 19.22% at the voltage of 14V. Moreover, the expansion rate of axial length and transverse width were 29.23% and 23.33% at 15V. Furthermore, the volume was obvious to increase at different therapeutic parameters in Table2. After 300s, the volume was 954.56 mm^3 at 14V, and when the heating-up time was 600s, the volume was 1576.54mm^3, which was extended with a rate up to 65.15%. At 15V, the volumes were 1175.13mm^3 and 2032.27mm^3 respectively while the heating-up time were 300s and 600s. As the voltage increasing from 14V to 15V, it was evident that the expansion rate of volume also grew accordingly ranging 65.15% to 72.94%.

In addition, the change of ablation results had the similar rule to expand by multi needle electrode in Table3. By the multi needle electrode, the rates of enlarging axial length and transverse width were 15.56% and 24.93% from 300s to 600s at 15V. Moreover, the expansion rate of volume at 14V was larger than that at 15V.

Through the simulation, acquired 383 sets of data were regarded as database. On the basis of the change regularity of ablation results, the expand rates of the axial length, transverse width and vertical depth are difficult to seek a linear rule. Thus, the relationship between therapeutic parameters and ablation results is the characteristic of nonlinearity. It's essential to generate logical method to illustrate the influence of therapeutic parameters on ablation results.

The treatment planning

In terms of above method, Fig.4 shows the predicting data and actual data for different prediction models of SVM, BP neural network and GRNN.

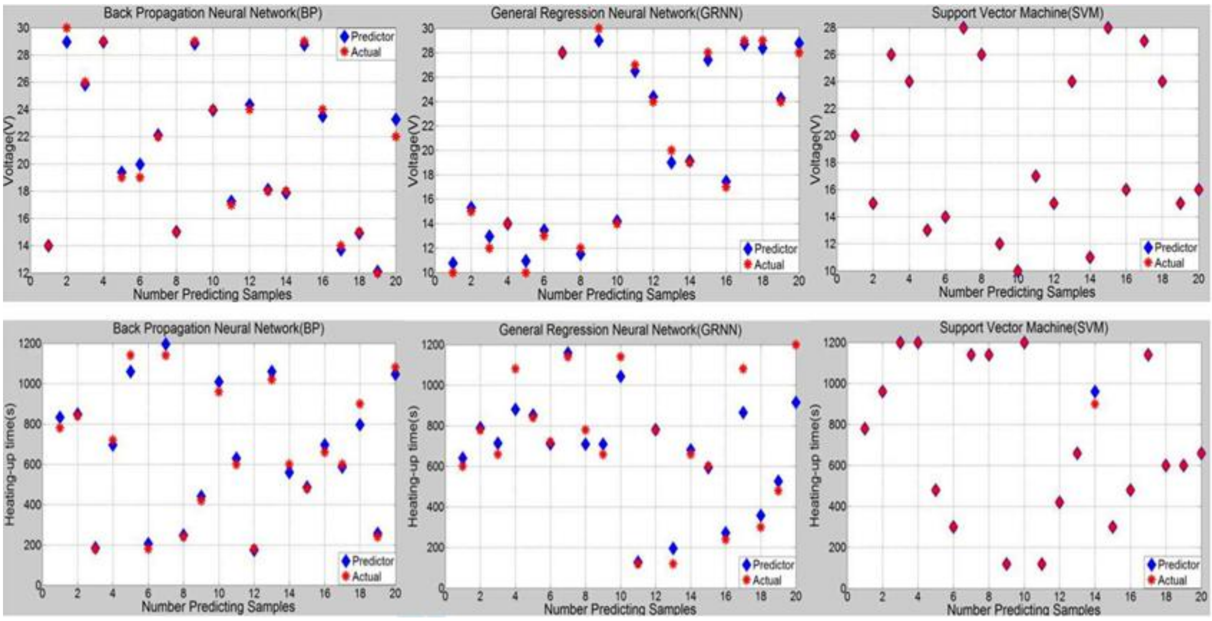


Figure4. The prediction results is to illustrate the accuracy by three models in selecting 20 sets of data. The icon of red asterisk represents actual data, which is about voltage and heating-up time by simulation. Meanwhile, the icon of blue rhombus stands for predictor data of voltage and heating-up time by three model. If the predictor data is

closer to actual data, the distance between blue rhombus and red asterisk is less. Beside, the complete covering of two kinds icons signifies that the predictor and actual data is the same, which means the high accuracy of prediction.

Although it has realized the goal to predict voltage and heating-up time by three models, the errors of prediction were different in Table4. By the statistical analysis between predicting data and actual data, we have calculated the error rate and correlation coefficients to evaluate the accuracy. In Table4, the maximum error rate of heating-up time prediction was 11.28% in GRNN model, meanwhile, the error rate of voltage prediction is also maximum in GRNN model. In the model of BP neural network, the prediction data was more accuracy than that in GRNN model; the error rates of voltage and heating-up time were 1.50% and 5.09%; the correlation coefficient were 0.996 and 0.991 respectively. However, in model SVM, the error rates were the smallest and the correlation coefficients were the closest to 1, no matter what prediction data, compared with that in other two models. Therefore, the model of SVM is the best one to predict in this database whether the error rate or the correlation coefficient.

Table 4. The statistical analysis in three models

	BP neural network		GRNN		SVM	
	Error rate(%)	Correlation coefficient	Error rate(%)	Correlation coefficient	Error rate(%)	Correlation coefficient
Voltage	1.50	0.996	3.22	0.992	0	1.000
Heating up time	5.09	0.991	11.28	0.964	0.33	0.999

In clinic, the voltage and heating-up time are estimated by the shape and size spinal tumor. Fig.5 shows the treatment planning to display the interface and function. In Fig.5, after writing the input value, the prediction data including voltage, heating-up time and volume could was shown in the interface. To illustrate the scientifically and precision of prediction, it was calculated the accuracy and correlation coefficient. Beyond that, the coverage was calculated to indicate whether ablating completely or not. Furthermore, the minimum radius was to descript the minimum radius by the multi needle electrode.

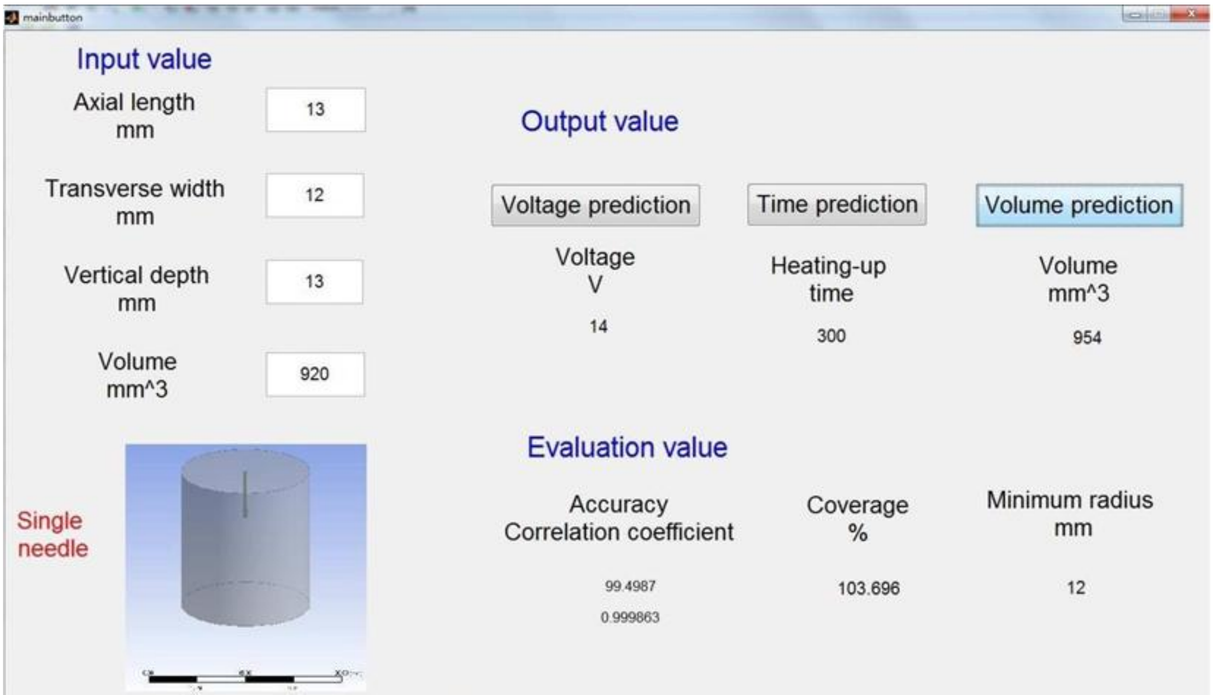


Figure5. The main program interface of software has three parts including input area, output area and evaluation area. According to input value about spinal tumor of axial length, transverse width, vertical depth and volume in input area, it's convenient to choosing different model containing single needle electrode model and multi needles electrode model. Moreover, the function is to predict correspondingly precise voltage, heating-up time and volume. The evaluation value is to verify the accuracy of prediction, based on the accuracy rate and correlation coefficient to show the accuracy, the coverage and minimum radius to explain whether complete cover.

Discussions and conclusions

This study describes the results of spinal tumor by radiofrequency ablation and the treatment planning to assist surgeons in surgical treatment.

Based on the clinical experience of ablation results, to make sure the ablation results scientifically and accurately is essential by numeral simulation analysis which can avoid the outside influential factor. In this study, the temperature distributions in Fig.2 are produced by different voltages and heating-up times, on the basis of the good meshing quality to improve calculating speed in addition to ensure the accuracy of simulation data. Compared with the previous study [5], the temperature distribution of simulation by RFA in this study is similar to that by MWA in previous study. It is also found that the highest temperature of ablation results is nearly located at the center of temperature distribution, and with increasing therapeutic parameters, the temperature distribution is increasing, and the center temperature is higher and higher.

It's believed that the spinal tumor ablation results by FEM in this study and other acquired results in clinical or ex-vivo studies could be combined together to verify the accuracy of data.

In the previous ex-vivo study [44], when the heating-up time was 600s and average energy was 1.52±0.76Kcal, the average long-axis diameter along the electrode was 3.05±0.46cm, meanwhile the average largest short-axis perpendicular diameters were 1.85±0.59cm and 1.26±0.48cm, moreover the average volume was 4.19±2.95cm^3. At the same conductions, the average energy 1.52±0.76Kcal is equal to the range from 14V-28V because of the conversion formula and mature research's conclusion [45]. When the voltage and heating-up time were 14V and 600s respectively, the axial length(X) was 1.64cm, the transverse width(Y) was 1.59cm, and the ablation volume was 1.57cm^3. Furthermore, 2.81cm axial length(X), 2.73cm transverse width(Y) and 7.29cm^3 volume were generated by 28V voltage and 600s heating-up time. Among that, the range of ablation volume is between 1.57cm^3 and 7.29cm^3, and other range of axial length(X) and transverse width(Y) is 1.64-2.81cm and 1.59-2.73cm. Compared with previous ablation results in ex-vivo spine, our simulation ablation results show that it has errors (0.33cm and 0.15cm) about ablation volume. Combined our ablation results with previous ablation at the same situations, there are some unavoidable elements to cause the significant errors, including different structures of electrode, different thermal parameters causing different heat transfer and the idealized numerical simulation model ignored some physiological parameters irrefutably. In spite of this, the ablation results are still of certain value for reference, which has the relatively accurate data of ablation results and the correct temperature distribution. Besides, the trendy of change in simulation of spinal tumor by RFA is the same to the situation in clinical. In consequence, the ablation results by single needle electrode are believed as the certain practical and significant reference and foundation in clinical.

Compared with other study [38] by multi needle electrode, the shape of our temperature distribution is resemblance. Due to the different tissue, we have changed the materials to illustrate the validity of simulation. The study has been reported that the diameter and the depth of the lesion were approximately 42mm and 36mm, and the lesion volume was approximately 19.3cm^3. At the same heating-up time, the simulation ablation results were 45mm(diameter), 35mm(depth) and 21.0cm^3 respectively, but relatively less error can be ignored caused by the other boundary condition, including 7.14%, 2.78% and 8.81%. Therefore, it's believed that the ablation results are regarded as basic database of treatment planning by numeral simulation.

In the terms of simulation data, we can find that at the same voltage, the expansion rate of axial length is bigger than that of transverse width with increasing heating-up time by single needle electrode. Moreover, as increasing the voltage, the expansion rates are all rising from 22.16% to 29.23% about the axial length. Actually the extending volume is more obvious than others in Table2 no matter which variable in therapeutic parameters. So the important factors are still voltage and heating-up time by the single needle electrode, and the axial length varies much more than transverse width by different heating-up time. Whereas, the expansion rate of axial length is smaller than that of transverse width with increasing heating-up time by multi needle electrode. Moreover, the expansion rate of R varies much more than the other two length, which ranges between 24.22% and 34.19%. Consequently, small tumor (maximum diameter<30.0mm) could be ablated by the single needle electrode and the large tumor (maximum diameter≥30.0mm) should be applied by the multi needle electrode.

Generally, in order to overcome the problem of the irregular shape of the spinal tumor, a treatment planning is provided to control the ablation region both completely and accurately. Due to the nonlinear relationship between therapeutic parameters and ablation results, it's advisable to select SVM method to predict data in treatment planning. It illustrates that the prediction data is approximately equal to actual data in the pictures in Fig.4.

Zheng [46] have built a prediction model by BP neural network model to illustrate feasibility of method in 0.988 correlation coefficient. Compared with the results by BP neural network model, the correlation coefficients are 0.999 and 0.996 respectively in prediction voltage and heating-up time. According to the study of Zheng, our study could be deemed to have accuracy to predict in BP neural network model. In fact, the correlation coefficients are 1 and 0.999 by SVM model, which is closer to 1 than that by BP neural network model. Besides, it has high accuracy for prediction, and the errors of prediction are respective 0 and 0.33% by SVM model. According to the prediction results, higher correlation coefficient and less error indicate that the prediction model by SVM is suitable for ablation in spinal tumor. And predicting the testing data describes the relationship between actual data and prediction data in Fig.4. Because the actual data is almost same to the prediction data, it explains the treatment planning is estimated successfully by SVM model in consequence. However, the reasons of prediction inaccuracy about other models attributes to the database characteristic and volume. Especially, the BP neural network model always depends on the rules of data, equivalently large data volume. Therefore, SVM model should be used in the system to predict surgical treatment of spinal tumors.

According to the SVM model and small sample by simulation, we have built the treatment planning, which could calculated the therapeutic parameters through inputting spinal tumor axial length, transverse width, vertical depth and volume. Meanwhile, it was calculated the accuracy and correlation coefficient. Beyond that, the coverage was calculated to indicate whether ablating completely or not. Therefore, this treatment planning have assisted surgeon to make precise surgical decision quickly and comprehensively.

Although the treatment planning based on numerical simulation is scientific and accurate, some functions are still generated imperfectly. Measuring axial length, transverse width and vertical depth of patient-specific spinal tumor should be provided in the interface of software. And because of the idealized numerical simulation model ignored some physiological parameters irrefutably, we will consider some medically important parameters in the model to acquire more accurate ablation results and consummate the database for reference in clinical. Besides, based on the complex environment of spinal tumor, we will study multi-material such as spinal cord, intervertebral disk, and spine and so on. In addition, it's essential to combine the imaging technology (CT, MR or X ray) with this treatment planning. And designing the path of electrode to insert spinal tumor seemly should be developed.

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